

# DIGITAL COMPUTER NEWSLETTER

**OFFICE OF NAVAL RESEARCH · MATHEMATICAL SCIENCES DIVISION**

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## Editorial Policy Notices

### EDITORIAL

The Digital Computer Newsletter, although a Department of the Navy publication, is not restricted to the publication of Navy-originated material. The Office of Naval Research welcomes contributions to the Newsletter from any source. The Newsletter is subjected to certain limitations in size which prevent publishing all the material received. However, items which are not printed are kept on file and are made available to interested personnel within the Government.

DCN is published quarterly (January, April, July, and October). Material for specific issues must be received by the editor at least three months in advance.

It is to be noted that the publication of information pertaining to commercial products does not, in any way, imply Navy approval of those products, nor does it mean that Navy vouches for the accuracy of the statements made by the various contributors. The information contained herein is to be considered only as being representative of the state-of-the-art and not as the sole product or technique available.

### CONTRIBUTIONS

The Office of Naval Research welcomes contributions to the Newsletter from any source. Your contributions will provide assistance in improving the contents of the publication, thereby making it an even better medium for the exchange of information between government laboratories, academic institutions, and industry. It is hoped that the readers will participate to an even greater extent than in the past in transmitting technical material and suggestions to

the editor for future issues. Material for specific issues must be received by the editor at least three months in advance. It is often impossible for the editor, because of limited time and personnel, to acknowledge individually all material received.

### CIRCULATION

The Newsletter is distributed, without charge, to interested military and government agencies, to contractors for the Federal Government, and to contributors of material for publication.

For many years, in addition to the ONR initial distribution, the Newsletter was reprinted by the Association for Computing Machinery as a supplement to their Journal and, more recently, as a supplement to their Communications. The Association decided that their Communications could better serve its members by concentrating on ACM editorial material. Accordingly, effective with the combined January-April 1961 issue, the Newsletter became available only by direct distribution from the Office of Naval Research.

Requests to receive the Newsletter regularly should be submitted to the editor. Contractors of the Federal Government should reference applicable contracts in their requests.

All communications pertaining to the Newsletter should be addressed to:

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## Computers and Data Processors, North America

### G. E. 600 Series

*General Electric Company  
Phoenix, Arizona*

Last July General Electric's Computer Department took the wraps off two of its new family of large-scale computers for business, scientific, and real-time use. Known as the Compatibles-600, they include the GE-625, with a 2-microsecond memory cycle, and the GE-635 with a 1-microsecond memory.

With the addition of the 600 line to its family, G.E.'s Computer Department now manufactures a full line of 12 computers, ranging from the GE-205 up to the 600 family. The largest computer in General Electric's line is now the GE-635. It adds well over a half-million numbers a second, carries a price tag of \$2 million and up, and leases from \$45,000 up into the hundred thousands per month. Deliveries of the new 600's will begin late this year.

Along with the new computers, a new line of G.E. magnetic tape units was also introduced. Available for both the GE-400 and GE-600, they employ pneumatic drive and photocell protective devices which essentially eliminate broken, scratched, and stretched tape.

Upward-compatible in both peripherals and programming packages, the Compatibles-600 can also use all peripherals presently available with the GE-400 medium-to-large-scale family of compatible computers.

Hardware and software were developed concurrently. The development team consisted of engineers, scientists, and mathematicians who were users, programmers, or supervisors of large-scale computer installations in several General Electric departments. First deliveries of the 600-line will be made with complete operating software.

The 600's feature a memory-oriented design. All system memory is directly

addressable by processors, input-output controllers, and real-time remote devices. Central memory can thus be accessed independently by the active system components, thereby achieving maximum over-all system utilization.

The 600 system will operate normally in a multiprogramming mode. This means two or more programs stored in memory will be executed virtually simultaneously by the processor on an interleaved, time-shared basis. The 600's also provide special features to make possible for the first time, practical multiprocessing, where several computers work together cooperatively to process large amounts of data.

The 600-line operates under control of an executive routine, termed General Comprehensive Operating Supervisor (GECOS). GECOS is said to be the most complete executive routine in the computer industry.

This is the first time a computer system has been designed to operate normally in a multiprogramming mode, for the purpose of operating the system at top efficiency, by placing maximum full-time demand on the processor, memory, and peripherals. By the end of the year, two systems will be tied together in multiprocessor operation at Phoenix.

The 600 line has a subsidiary advantage in being particularly well adapted to military applications, with total mission compatibility for commercial, aerospace, and ground-based military computers. Programming for General Electric's military computers, the A-605, M-605, and M-625 may be developed, checked, and debugged on the GE-625 and 635.

Modular components and software design providing for horizontal expansion of the system, instead of upward extension to higher-powered systems, permit exact tailoring of initial system

and facilitate future growth. Ability to expand by adding identical components which operate in parallel also enhances system reliability.

The newly-announced magnetic tape subsystems are for both seven- and nine-channel operation. Transfer rates are up to 160,000 characters per second. They include "cross-bar" tape control which permits multiple access of transports on the subsystem. Full tape compatibility is provided within standards of the American Standards Committee of Information Interchange (ASCII).

Other peripherals include Disc and Drum Storage subsystems; 900-cpm card reader; 300-cpm card punch; 136-column, 1200-line-per-minute printer; and Datanet-30 data communications processor.

Programming packages available with the 600's include the General Comprehensive Operating Supervisor; Macro Assembly Program; FORTRAN IV; FORTRAN II to FORTRAN IV SIFT; COBOL-61 extended, with report writer and sort; application packages such as APT, PERT/cost, LP, and Mathpac; and a variety of utility and service routines.

#### COMPATIBLES-600: GE-625 AND GE-635

**Application Area:** Across the board in Business, Scientific, and Real Time

#### Specifications Common to Both

Electronics	Solid state
Alphanumeric character	6 bits
Word length	36 bits plus parity
Characters per word	6
Memory type	Coincident current core
Floating point precision:	
Single	8 to 21 decimal digits
Double	19 to 21 decimal digits
Number of directly addressable words of core storage per processor	262,144 maximum
Data manipulation and arithmetic	BCD/binary

Instruction format	36 bits binary
Address	12 bits binary
OpCode	9 bits binary
Tag	6 bits binary
Number of basic instructions	170
Number of index registers	8 plus
Number of I/O channels	8 or more

#### Salient Features

Integrated hardware/software system  
Designed by large-scale users  
Multiprogramming  
Multiprocessing  
Modular components  
Modular software design  
Real-time oriented system  
Facilitates data communication

#### Programming Packages for Compatibles/600

General Comprehensive Operating Supervisor  
Macro assembly program  
FORTRAN IV  
FORTRAN II TO FORTRAN IV SIFT  
COBOL-61 extended with report writer and sort  
Application packages, such as:  
    APT  
    PERT/cost  
    LP  
    Mathpac  
And a wide variety of utility and service routines

#### Individual Specifications

	<u>GE-625</u> (micro- seconds)	<u>GE-635</u> (micro- seconds)
Total Cycle Time	2 $\mu$ s/2-word pull	1 $\mu$ s/2-word pull
Fixed Point Add	3.0	1.8
Multiply	7.0	7.0
Divide	14.5	14.2
Floating Point Add	3.0	2.7
Multiply	6.0	5.9
Divide	14.5	14.2

## IBM System 360

International Business Machines Corporation  
White Plains, New York 10601

### INTRODUCTION

A new generation of IBM electronic computing equipment was introduced in April by International Business Machines Corporation. The new equipment is known as the IBM System/360. It combines microelectronic technology, which makes possible operating speeds measured in billionths of a second, with significant advances in the concepts of computer organization.

System/360 is a single system which spans the performance range of virtually all current IBM computers, from the widely used 1401 to nearly twice that of the most powerful computer previously built by the company. It was developed to perform information handling jobs encompassing all types of applications. Within the system are models 50, 60, 62, and 70.

System/360 includes in its central processors 19 combinations of graduated speed and memory capacity. Incorporated with these are more than 40 types of peripheral equipment which store information and enter it into and retrieve it from the computer. Built-in communications capability makes System/360 available to remote terminals, regardless of distance.

The equipment is supported by programs which enable System/360 to schedule its own activities for non-stop computing that makes most efficient use of system capabilities.

Internal processing power of the largest System/360 configuration is approximately 50 times greater than that of the smallest. The system's machine cycle time—basic pulse beat of a computer—ranges from 1 millionth of a second to only 200 billionths of a second.

System/360 core storage memory capacity ranges from 8000 characters of information to more than 8,000,000. Information storage devices linked to the system can store additional billions of characters of data and make them available for processing at varying speeds, depending on need.

It is the balancing of these factors—all available within a single system using one set of programming instructions—that will make it possible for a user to select a configuration suited to his own requirements for both commercial and scientific computing. With the

same type of input/output devices, a user can expand his System/360 to any point in its performance range, without reprogramming.

Some of the most significant advances represented by the new IBM System/360 include:

**Solid Logic Technology.** Microelectronic circuits, a product of IBM's Solid Logic Technology, make up the system's basic componency. System/360 is the first commercially available data processing system whose design is based on the use of microminiaturized computer circuits.

Called logic circuits because they carry and control the electrical impulses which represent information within a computer, these tiny devices operate at speeds ranging from 300 down to six billionths-of-a-second. Transistors and diodes mounted on the circuits are only 28 thousandths-of-an-inch square and are protected by a film of glass 60 millionths-of-an-inch thick.

**Memory Power.** A hierarchy of memories within System/360 makes information in core storage available at varying speeds. Small local store memories operate in as little as 200 billionths-of-a-second. Control memories operate in as little as 250 billionths-of-a-second. Powerful main memories—containing up to 524,000 characters of information—range from 2.5 millionths of a second down to 1 millionth of a second.

A key development provides 8,000,000 characters in bulk core storage, each character available in 8 millionths of a second, and each at the direct command of a computer programmer. This is over sixty times more directly addressable characters than were previously available in IBM computers. The computer's historic limitations on memory size are overcome by this development.

**Application Versatility.** The traditional distinction between computers for commercial and scientific use is eliminated in System/360. Users will be able to process both business and scientific problems, or a combination of the two, with equal effectiveness. This versatility is reinforced by the variety of peripheral equipment which is part of the system.

**Communications Capability.** Built into System/360 is the ability to respond to inquiries

and messages from remote locations at any time. Hundreds of terminal devices can communicate simultaneously with a system while the computer continues to process the basic job on which it is working.

System/360 monthly rentals will range from \$2,700 for a basic configuration to \$115,000 for a typical large multisystem configuration. Comparable purchase prices range from \$133,000 to \$5,500,000.

Deliveries of the small configurations of System/360 are scheduled to begin in the third quarter of 1965. Deliveries of the largest configurations are scheduled to begin in the first quarter of 1966.

Forty-four peripheral computer devices are part of IBM System/360. Twenty-six of the units are being offered for the first time.

The new equipment includes:

The IBM 2321 data cell drive—a random access device that can store 400 million alphanumeric characters or up to 800 million decimal digits. Multiple drives, providing a storage capacity of billions of characters of information, can be linked to System/360.

The IBM 2250 display console—a visual display unit that provides a "window into the computer." It can display a message of thousands of characters of information, or tables, charts, graphs, and the lines and curves of drawings as a series of points. A light pen, available with the display, can detect information that has been displayed on the screen and enables an operator to change the information under program control.

The IBM 7340 hypertape drive—a unit which uses magnetic tape packaged in cartridge form, transfers data at 340,000 alphanumeric characters a second, or 680,000 digits a second. A cartridge holds more than 65 million digits.

The IBM 7772 audio response unit—a device which can link System/360 to a telephone network to provide voice responses to inquiries made from telephone-type terminals. The audio response is composed from a vocabulary pre-recorded in a digitally coded voice on a disk storage device.

The IBM 2301 drum storage—a random access storage device for approximately four million alphanumeric characters or up to eight million digits, which can be retrieved at a rate of 1.2 million characters a second. Four units,

providing on-line storage for 16 million alphanumeric characters, can be linked to a processor.

The IBM 1070 process communication system—a communication terminal for on-line data transmission between remote process input/output stations and a central computer. It provides real-time control of natural gas and oil pipe lines, petroleum refineries, iron and steel works, or batch process manufacturing operations.

The System's peripheral equipment includes storage devices, visual display units, communications equipment, card read punches, printers, a paper tape reader, and character recognition devices. A summary of some types follow:

## STORAGE DEVICES

### Storage Files

**IBM 2321 Data Cell Drive.** The 2321 data cell drive provides large bulk storage at low cost. Billions of characters of alphanumeric or digital data can be stored by linking multiple drives. Eight data cell drives, with up to 6.4 billion digits, can be linked to one control unit. Additional files can be linked to other control units in the same system. Each drive holds 400 alphanumeric characters of information or up to 800 million digits and is designed so that data cells are removable and interchangeable in increments of 40 million characters or up to 80 million digits.

Information is stored on and retrieved from magnetic strips, which are held in cells mounted vertically around a rotating cylinder. To retrieve or write information, the data cell drive's positioning system rotates the cell cylinder to locate the specific 10-strip group needed and place it beneath an access station. At the station, the particular strip containing the desired information is withdrawn. The strip is moved past a read/write head for transfer of data to the computer, and the strip then is returned to its original location. This process requires approximately 450 milliseconds. Each group of 200 strips, or 40 million characters, is called a data cell and can be removed and replaced by another group. This is especially useful when records, such as insurance policies, are being updated.

The magnetic tape strips used for storing information measure 2-1/4 inches wide by 13 inches long by 0.005 inch thick. One side has an iron-oxide coating for magnetic recording

and the other side has an anti-static coating of carbon. Each strip has an individual coding tab, identifying its position among the 200 strips in a data cell.

A handle cover, which protects strips from contamination during handling, is available for removing data cells. One data cell can be removed and replaced by another in less than 30 seconds.

The 2321 has a five-position, 20-track read/write head. Each strip has 100 addressable recording tracks providing storage of approximately 200,000 (eight-bit) characters of information. Recording is accomplished in serial fashion at a strip velocity of 250 inches per second which produces an information transfer rate of about 54,700 characters per second.

Access time varies from 95 milliseconds to 600 milliseconds, depending on the addressed strip position and data arrangement in each data cell. Access time is the time required to position the mechanism to read a strip, which includes locating the strip on the drum, reading, writing, and write-checking it.

**IBM 2311 Disk Storage Drive.** The IBM 2311 disk storage drive holds 7.25 million alphanumeric characters of information, or up to 14.5 million digits, in its 10-pound removable and interchangeable disk pack. It packs into six, 14-inch-diameter disks almost twice as much information as was stored in the computer-sized IBM RAMAC 305 when it was first introduced in September, 1956. Up to eight 2311 drives can be attached to one control unit to provide an on-line capacity of 58 million characters or up to 116 million digits.

Unlimited storage capacity is possible with the 2311, since each disk pack can be removed and replaced with another in less than a minute. A System/360 user can maintain a disk pack for each of his major files such as inventory, accounts payable, payroll, and work-in-process. When a particular job is about to be processed, the specific disk pack for the job can be placed quickly on the 2311 drive. This means that large volumes of input data are available for processing at random or in sequence.

The six disks are vertically mounted one-half inch apart. Each of the 10 inside disk surfaces has 203 tracks and the disks rotate at a speed of 2400 revolutions a minute. The two outside disk surfaces are used as protective plates.

The access mechanism of the 2311 has ten horizontal access arms vertically mounted in pairs, with each pair positioned to read or write on the corresponding upper or lower disk surface. The average access time of the 2311 is 85 milliseconds. This is almost twice as fast as the 1311, the 2311's predecessor, which has a capacity of two million characters.

**IBM 1302 Disk Storage.** The 1302 disk storage can record and retrieve data either randomly or sequentially. The random capability permits immediate access to specific areas of information without the need to examine sequentially all the data in the file. A user can maintain up-to-the-second files and make frequent retrievals of the data stored as a result of the fast information transfer rate of 156,000 characters a second.

The 1302 is available in two models. One model contains one disk storage module consisting of a stack of 25 disks, or 50 surfaces, and two access mechanisms. Forty-six of the surfaces are used to store data for a total capacity of 112 million alphanumeric characters, or up to 224 million digits. The other model of the 1302 contains two disk storage modules. Up to four modules may be connected to System/360 configurations for on-line random access to 448 million eight-bit alphanumeric characters or up to 896 million digits.

The disks spin at 1800 revolutions a minute. Each disk surface is divided into 500 tracks. Information is written on, or read from, a track by one of 48 read/write heads mounted on a comb-like access mechanism.

The availability of a hierarchy of random access storage files enables the System/360 user to balance the speed of recording and retrieving data within the volume of information retained for immediate access to a processor.

The 2321, 2311, and 1302 storage files are being manufactured at IBM's San Jose, Calif., plant. They utilize the IBM 2841 storage control unit.

#### Magnetic Tape Equipment

**IBM 7340 Hypertape Drive.** The new ultra-speed IBM 7340 hypertape drives are designed to read or record information at a rate of 340,000 alphanumeric characters a second or up to 680,000 digits a second. This represents the fastest commercially-available magnetic tape system in the world. The drive operates at

either of two densities, 1511 or 3022 bits an inch. Also available is a hypertape drive that operates at 170,000 alphanumeric characters a second, or up to 340,000 digits a second.

Hypertape drives utilize magnetic tape packaged in cartridge form which eliminates tape contamination or damage from manual handling. An automatic cartridge loader for automatic loading and unloading of magnetic tape is available. It holds a cartridge in reserve and automatically moves this reserve unit into position for use by the processor as soon as processing of the first cartridge has been completed.

Read backward, which speeds tape sorting by eliminating certain rewinds, and automatic threading and unthreading of tape are standard features on the 7340.

**IBM 2802 Hypertape Control Unit.** A hypertape control unit, the IBM 2802, attaches to a selector or multiplexor channel of the processor and can control up to eight drives. A feature is available that enables the 2802 to address as many as 16 drives when used with the IBM 2816 tape switching unit, model 2. This unit allows up to 16 hypertape drives to be shared by up to four data channels on the same or separate System/360 processors.

**IBM 2400 Series Nine-Channel Magnetic Tape Unit.** The new IBM 2400 series nine-channel magnetic tape unit reads and records information in nine data tracks across 1/2-inch wide tape. Also available with the 2400 series, is a seven-track compatibility feature which enables reading and writing of data at high speeds. Magnetic tape is a basic storage medium for computers.

The 2400 series is available in four types. Each type comes in three models, with different information transfer rates. These models are: 22,500 alphanumeric characters or up to 45,000 digits a second; 45,000 alphanumeric characters or up to 90,000 digits a second; and 90,000 alphanumeric characters or up to 180,000 digits a second.

The four types of magnetic tape units are:

- 2401—a single tape drive;
- 2402—a double drive;
- 2403—a single drive with a built-in control for either reading or writing information; and

- 2404—a single drive with a built-in control for simultaneous reading and writing.

In addition, there are two tape control units:

- 2803—single channel control for operating up to eight drives,
- 2804—two-channel control for operating up to eight drives.

Each of the built-in control units can operate as many as eight tape drives. On the 2404, the simultaneous control is attached to two channels in a manner that permits a read operation on one tape drive to be overlapped with a simultaneous write operation. The controls attach to a selector or a multiplexor channel and operate in the burst mode. Types 2401 and 2402 utilize the IBM 2803 and 2804 tape control. The 2401 and 2402 drives also can be attached to the 2403 and 2404 drives through the built-in control unit. The 2803 is a single-channel unit for read or write control; the 2804 is a double-channel unit for read while write control. Both units also can operate up to eight tape drives.

The 2816 model 1 tape switching unit can be used with the 2400 series. The read backward feature is standard on all 2400 drives.

The 7340 hypertape drives and the 2400 series can be used separately on all models of System/360. On System/360 Models 50, 60, 62, and 70, it is possible to use a combination of hypertape and 2400 tape units. Tape drives and controls are manufactured at IBM's Poughkeepsie plant.

#### Drum Storage

**IBM 2301.** Two drum storage units are available with System/360. One, the IBM 2301 drum storage, has a capacity of four million alphanumeric characters of information or up to eight million digits. It can transfer information to a processor at a rate of 1.2 million characters a second. The 2301 is designed for operation with System/360 Models 50, 60, 62, and 70.

Drum storage devices operate by assembling characters of information from four read/write heads simultaneously, rather than by assembling bits from a single head as they are written one after the other. This results in the extremely high information character rate of the 2301 drum storage.

**IBM 7320.** The other drum storage is the IBM 7320 which has a capacity of 808,000 alphanumeric characters of information available at a rate of 203,000 characters a second.

The 2301 achieves its increase in capacity over the 7320 from utilization of double bit, double track density recording, while maintaining an 8.6-millisecond average rotational delay. Because of their overall performance, the drums can be used for program storage to make possible faster compiling of information. It also can be used to store frequently used sub-routines which must be available when needed by the processor. The indexing capability of the 2301 and 7320 minimizes the time required to locate information on disk storage or magnetic tape. Other uses include storage of tables such as those for mathematical functions, program language translations and as an extension of core storage.

Up to eight 7320 drum storage units can be linked to the 2841 control unit for a total on-line random access storage of 6.4 million characters. The 2301 requires the IBM 2820 drum storage control which can accommodate up to four 2301 drums for a total of 16 million alphanumeric characters or up to 32 million digits.

The drum storage devices are manufactured at IBM's Kingston, N.Y. plant.

## VISUAL DISPLAY UNITS

### Display Unit

**IBM 2250.** The IBM 2250 display unit provides a dynamic visual presentation of information stored in the computer or in storage files, drums, and tapes. An operator at the display can monitor the progress of his program or solution, and can modify and intervene as necessary.

The 2250 may be used to display immediately an updated account record as required to respond to an inquiry. Corrections to the record may be made directly on the displayed information, and the corrected record is immediately stored. The 2250 also can be programmed to present to the system's operator or programmer partial results, problem checks, graphs of mathematical results and other instantaneous computational output.

The unit can be used as the computer operator console, for engineering record keeping

and updating, as a time-shared scientific computing terminal, for information retrieval, data acquisition monitoring, data reduction display, process control supervision, order entry, and inventory inquiry and updating.

The major element of the 2250 is a console with a 12-inch square display screen (a 21-inch cathode ray tube) on which tables, graphs, charts, alphanumeric characters, or the lines and curves of drawings can be displayed as a series of points. When the full display area is used, 3848 alphanumeric characters—the contents of a page of information—can be viewed. A built-in electronic marker helps the operator edit messages. When the display console is used as a point plotter, it can plot graphs, charts, and drawings with the precision of a square matrix of 1024 points, or more than one million individually addressable points.

Buffer storage for the 2250 is available in 4096 and 8192 character capacities. These buffer storage units hold points, lines, and position instructions which may be read from or written at a maximum rate of 238,095 characters a second.

Other features of the 2250 are:

- A typewriter-like keyboard for entry of all alphanumeric information and control of the electronic marker;
- A light pen for communication between operator and processor. When this pen-like device is pointed at information displayed on the screen, it detects light from the cathode ray tube when a beam passes within its field of view. The pen's response is transmitted to the computer, which relates the computer's action to the section of the image being displayed. In this way, the operator can delete or add text, maintain tighter control over the program and choose alternative courses of action.
- The IBM 2840 display control which permits up to eight display units to operate in an economical time-sharing configuration. Up to 16,384 characters of storage are available with the 2840.
- A keyboard which makes interpretive operations possible. Its function for a particular job is assigned by the computer program and the keys for that job are identified by removable illuminated overlays.
- An operator control panel for those processors where the display is used in place of the typewriter control console.

The 2250 is being manufactured at the company's Kingston plant.

#### Inquiry Display Terminal

**IBM 1015.** The IBM 1015 inquiry display terminal is designed to operate as an inquiry device for System/360 Models 30, 40, and 50.

Information is placed into the computer through the 1015's alphanumeric keyboard and is simultaneously displayed on its four-inch-square screen. The 1015 then displays a reply to the inquiry on its screen.

Information is displayed at a rate of 600 characters a second, about 40 times faster than that produced for an operator by means of a type-out. The viewing area has a 30-line capacity of 40 characters each. To reuse the display, once 1200 characters have been displayed and the inquiry has been answered, requires only a push of the "erase" button. The standard 36 alphanumeric characters (A through Z, 0 to 9) plus 23 special characters are available.

The 1015 which utilizes the IBM 1016 control unit, is manufactured at IBM's Endicott, N.Y., plant.

### COMMUNICATIONS EQUIPMENT

#### Process Communication System

**IBM 1070.** The new IBM 1070 process communication system is designed for on-line data transmission between remote process locations and a central computer. It operates in three different environments:

1. Where transmission lines over long distances connect several remote process input/output stations to a central computer for real-time control, i.e., of natural gas and oil pipe lines.
2. Where several input/output units located in a group near a process require data transmission facilities for connection to a central computer providing real-time control of facilities such as petroleum refineries, or iron and steel works; and
3. Where input/output units are connected directly to the process, in addition to operator-oriented terminal stations, and they use data transmission facilities for connection to a common computer as in batch process manufacturing operations.

Any model of System/360 may use appropriate optional features developed to meet the requirements of specific industrial process control application. These features might include the 1074 binary and 1076 digital display, the 1076 manual binary and 1077 decimal input. The IBM 1053 output printer can be used with the 1070.

Through the use of a multiplexor terminal unit, the 1071, the System can connect, via four transmission lines, up to 98 terminal stations to the central processor. The processor controls all transmission sequences to and from the terminal stations, performs, checks and handles the required calculations. Input/output devices such as storage files, magnetic tapes, visual displays, and printers also can be attached to the processor. These terminal stations are designed to handle a user's standard control system input/output devices and transducers. They will convert the signals between the 1070 and the devices in the process.

The transmission of data to or from the terminal stations is performed on multi-drop transmission channels in half-duplex mode at speeds of 134.5 or 600 bits a second, which corresponds, respectively, to 14.8 or 66.6 characters a second. The transmission is buffered into the processor for greater system efficiency.

System/360 can combine 1070 terminal stations with other IBM terminals as the 1030 data collection system and the 1050 data communication system.

The 1070, which was developed by IBM's Nordic Laboratory in Stockholm, Sweden, is being manufactured at San Jose.

#### Audio Response Unit

**IBM 7772.** The IBM 7772 audio response unit can be attached to System/360 Models 30, 40, and 50 through their multiplexor channels. It links the processor with a telephone network to provide a recorded voice response to inquiries made from telephone-type terminals. The audio response is assembled from a vocabulary which is pre-recorded in a digitally coded voice on a disk storage file connected to the computer.

Inquiries to the 7772 are received as a series of digits either dialed or keyed from an ordinary telephone. The audio response unit buffers each digit. Then these are transferred to the processor's core storage and assembled

into a complete message. After processing the message, the computer assembles a digitally coded voice output response which is transferred to the 7772. The 7772 converts it to actual voice signals and sends it to the inquiring party as the audio response.

The 7772 has two basic input/output lines, but can be expanded to eight lines.

The audio response unit was developed by IBM's laboratory at LaGaudie, France. It is being manufactured at the company's Kingston plant.

#### **Data Adapter Unit**

**IBM 2701.** The IBM 2701 data adapter unit provides System/360 with greatly expanded input/output device capability. It provides direct connection for a variety of remote and local external devices--the 1050, teletypewriter terminals, telemetry terminals, test instrumentation, and data acquisition equipment.

The unit attaches to a selector channel or multiplexor channel. A selector channel handles high-speed input/output devices. It is overlapped with other selector channels and a multiplexor channel, in a processor's input/output control element, to provide simultaneous operations.

When a selector channel is used, only one device at a time can read data into that channel, although as many as eight input/output control units can be connected to it. A multiplexor channel can handle many low or medium speed devices simultaneously on a character-by-character basis or a single device in a burst of characters.

The maximum data rate capability of the 2701 generally is specified by the particular transmission interface adapter used, the input/output channel capacity and the overall systems configuration.

The parallel data adapter feature allows external devices to be connected to the 2701 through a half duplex mode, and permits transmitting and receiving information in one direction at a time. This feature contains 11 control lines and 16 data lines and can be expanded, as an option, to 48 lines in steps of eight.

Another feature, designed primarily for handling telemetry data, permits the 2701 to handle up to two million bits a second. Other 2701 adapters enable switching of electrical

contacts under computer control, determination of the status of a particular test instrument during a process control job, and control of data transmission between the computer and private wire telegraph units or 1050 data communication systems.

The 2701 is being manufactured at IBM's Poughkeepsie plant.

#### **Transmission Control**

**IBM 2702.** The IBM 2702 transmission control, which operates at lower speeds than the 2701, is designed for use with System/360 Models 30, 40, and 50. It directs and controls information that flows between the processor and many remote terminals such as the 1070, 1050, 1030, and 1060 data communications systems.

The 2702 utilizes the multiplexor channel of the processor. The link with the remote terminals is via private and commercial common carrier transmission facilities.

Up to eight 2702 units can be attached to a multiplexor channel and operation of each is in the interleaved mode. The 2702 accepts electrical signals sequentially from a number of communications lines, converts these signals into characters and transfers the characters to the processor. It transfers information from the System/360 processor to the remote terminal serially, or one bit at a time. Under interleaved operation, there is an eight-bit buffer per line on the multiplexor channel. Messages to and from the 2702 can be of any length.

The basic data communications unit has up to 15 half-duplex lines. It operates at speeds from 75 to 600 bits per second in a start/stop mode.

The 2702 is manufactured at IBM's Poughkeepsie plant.

#### **Other Terminals**

Several existing communications systems will be available for use with System/360 Models 30, 40, and 50:

**IBM 7770.** The IBM 7770 audio response unit provides verbal replies to inquiries about information stored in a System/360. It provides immediate telephone access to millions of business facts on file in a company's computer. Like the 7772, it attaches to a processor through the multiplexor channel. The audio response

unit has four basic lines and is expandable to either 16 or 48. It, too, can buffer inquiries. The 7770's audio response is composed from a vocabulary pre-recorded on a magnetic drum. The unit is manufactured at the company's Kingston plant.

**IBM 1030.** The IBM 1030 data collection system can gather manufacturing information from electronic in-plant reporting stations and transmit it directly to System/360. The information is processed as it is received. Reports can be produced which indicate, for example, job cost or machine utilization. Information can enter the processor in several ways, including punched card, plastic badge, keyboard, or data cartridge. The latter logs production data on a pocket-sized recording device that the employee maintains at his work station.

The 1030 system includes 1031 input stations, a 1033 printer to allow two-way communication between the key plant locations and the computer, the 1032 digital time unit to log the time of each transmission, and the 1034 card punch for recording data in cards for later processing. The 1030 is manufactured at IBM's Rochester, Minn., facilities.

**IBM 1060.** The IBM 1060 data communication system links teller window locations in savings banks, savings and loan associations, and commercial banks with either the main office of the institution or a branch office, where a System/360 is located. The 1060 system consists of the 1062 teller terminal which is linked to the processor over communications lines through the 1061 control unit and either the 2701 or 2702. Transaction data can be transmitted from a keyboard at a speed of 14.8 characters a second.

The operator of a 1062 handles a savings account deposit by keying in the account number which is simultaneously flashed to the processor and printed on the teller's record tape. Next the deposit amount and the type of transaction are keyed into the terminal, flashed to the computer and printed on the tape. The old balance from the customer's passbook is checked for agreement with the old balance recorded in the computer, then the computer updates the account and prepares and transmits a reply message to the terminal. The printing unit records the data, first on the teller record tape, then on the passbook, where data, transaction amount, new balance, and teller identification are printed from the computer. If any interest is due, that is automatically posted at the same time. The 1062 teller terminal is

manufactured at the company's Rochester, plant.

**IBM 1050.** The IBM 1050 data communication system is used as an inquiry and data entry station when linked to a computer. Two or more 1050 systems can communicate with each other or can be used independently for source recording, document writing, preparation of data for transmission, and conversion of data from one medium to another.

The 1050, transmitting at up to 14.8 characters a second, can use existing communication lines, private or public. Modulating-demodulating units provided by the common carriers are placed at each sending and receiving location to provide compatibility between data processing equipment and communication circuits. In on-line operations, inquiries or data to be transmitted are entered in the 1050. The data passes from the input unit to the 1051 control unit which places the data on the communication line via the common carrier unit. If the receiving station is another 1050, the message enters via the 1051, which checks it for errors and passes it to whichever output element has been selected by the receiving operator. Coordination of the 1050's input and output elements and internal communication lines is performed by the IBM 1051 control unit. All incoming data passes through the 1051 which checks it for transmission or recording errors and directs it to the correct output element.

There are six input and output units that make up the 1050 system. These include the 1052 printer-keyboard, the 1053 printer, the 1054 paper tape reader, the 1055 paper tape punch, the 1056 card reader and 1057/1058 card punch. The 1050 is manufactured at the company's Endicott plant.

#### CARD READ PUNCHES

Two card read punches are available with System/360. They are:

- The IBM 1442 which reads 400 cards a minute and punches 160 columns a second.
- The IBM 1402 which reads 800 cards a minute and punches 250 cards a minute and can be used with System/360 Models 30, 40, and 50. The 1402 requires the IBM 2821 control unit.

These devices are manufactured at the company's Rochester plant.

Several existing printers and a new unit will be available with the System/360. They are:

IBM 2201 Model 3. The new IBM 2201 model 3 printer produces up to 1100 lines a minute of alphanumeric information. It is possible to achieve 1400 lines a minute by using a preferred character set—a rearrangement of the alphanumeric characters. It is enclosed in a hydraulically operated acoustical cover to minimize noise.

IBM 1403 Models 2 and 3. The IBM 1403 model 2 a 600 line-a-minute alphanumeric printer. The IBM 1403 model 3 and 100 line-a-minute alphanumeric printer.

IBM 1404 Model 2. The IBM 1404 model 2 for printed paper and card document output.

These units are designed for use with System/360 Models 30, 40, and 50, and require the 2821 control unit.

IBM 1443. The IBM 1443 printer, a 240 line-a-minute alphanumeric unit has a built-in control unit.

All printers are manufactured at Endicott.

#### PAPER TAPE READER

IBM 2671. The IBM 2671 paper tape reader reads five to eight-track paper tape, as well as telegraphic codes, at up to 1000 characters per second. The reader is controlled by the IBM 2822 paper tape reader control unit, which provides status and data information to System/360 from the 2671.

These units were developed at IBM's LaGarde, France, laboratory and are being manufactured at Endicott.

#### CHARACTER RECOGNITION DEVICES

Several existing magnetic ink and optical character recognition devices will be available:

IBM 1231. The IBM 1231 optical mark page reader scans ordinary pencil marks made on 8-1/2 x 11-inch data sheets and simultaneously transmits the information to a System/360 Model 30 for preparing summary reports. It can optically read data sheets at a rate of up to 2000 sheets an hour. The device is manufactured at the company's Rochester plant.

IBM 1428. The IBM 1428 optical reader reads type and/or printed alphabetical and numerical data on paper documents of various sizes for direct input to a System/360 Model 30. Reading speed is up to 480 characters a second from as many as 400 documents a minute. This unit is manufactured at Endicott.

IBM 1418. The IBM 1418 optical character reader, available with the System/360 Model 30 reads numerical data printed in widely used type styles on paper or card documents at a rate of 480 characters a second. As many as 400 documents a minute may be read. The printed data automatically is translated into machine language for direct input to the processor. This unit is being manufactured at Endicott.

IBM 1419. The IBM 1419 magnetic character reader which processes bank checks at speeds up to 1600 a minute and postal money orders at speeds up to 1960 a minute. Designed for use with the System/360 Models 30 and 40, it is being manufactured at the Endicott plant.

IBM 1412. The IBM 1412 magnetic character reader handles paper checks and deposit slips and makes possible direct input of data from paper documents into a System/360 Model 30. It reads up to 950 documents a minute. The 1412 is being manufactured at Endicott.

## Computing Centers

### An Integrated Computer System Concept for Research and Education

*California Institute of Technology Computing Center  
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Until recently, applications of digital computers by research and educational institutions have concentrated on the features of high data processing speed and large fast access memory. Of equal or perhaps greater importance is the enhancement of the ease of communication between the user and the central processor in terms of rapid communication or turn around times for a large number of diversified uses. During the past 2 years McCann, Hebert, and Ray, of the California Institute of Technology Computing Center, have been engaged in the development of a system concept which will permit interplexed operations from a large number of remote input-output stations and peripheral special purpose data processors. This work has been directed toward the following three general classes of applications:

1. Production computing and compiling with fast turn around.
2. Direct data collection and on-line control analysis for large scale experimental research.
3. Creative programming efforts of individuals at their optimum thought process rate and interacting directly with the computer.

The performance of these functions at remote locations from the central computing system has been achieved by the development of a basic remote typewriter console suitable for human communication with the computer, a standard form of remote display, and a series of special purpose data collection and peripheral processing stations.

#### COMPUTING SYSTEM CONFIGURATION

The basic features of the system we have chosen are illustrated schematically in Fig. 1. The heart of the system is the interconnected

IBM 7094 and 7040, each with 32,000-word core memories. The interconnections consist of a practically instantaneous trapping mode, a pseudo tape drive interconnection for core-to-core transfer, two 1301 disk units providing 18.6 million words of memory and the shared magnetic tape units. Communication between the 7040 and the remote stations and other portions of the system complex is facilitated by the IBM 7288 multiplexor. This provides up to 48 channels of communication, each with an information transfer rate of up to 375,000, six-bit characters per second. Additional interplexing of each channel accommodates a multiplicity of lower data rate channels. The principal buildings of the Institute are all within two or three thousand feet of the Computing Center and connected by large underground steam tunnels. It was therefore economical and practical to interconnect all remote stations by combinations of concentric cables and standard telephone leads. Three types of communication systems were developed by the Computing Center staff, one with a data rate of 200,000 characters per second, another with 1500, and a third with 150.

The IBM 7094 computer provides the capability for the rapid calculation of large, complex problems, but its efficiency as a powerful, centralized calculator is seriously affected when it must simultaneously control a large number of sophisticated input-output devices. This is particularly true when several of these devices may require a real time response. Even the addition of special, readily available, features such as a Direct Data connection does not provide enough simultaneity in the hardware, and the difficulties encountered in providing more than one level of program interplexing require that additional computing capability be added to the basic 7094 to satisfy the requirements discussed above. For this reason an IBM 7040 with selected auxiliary equipment was

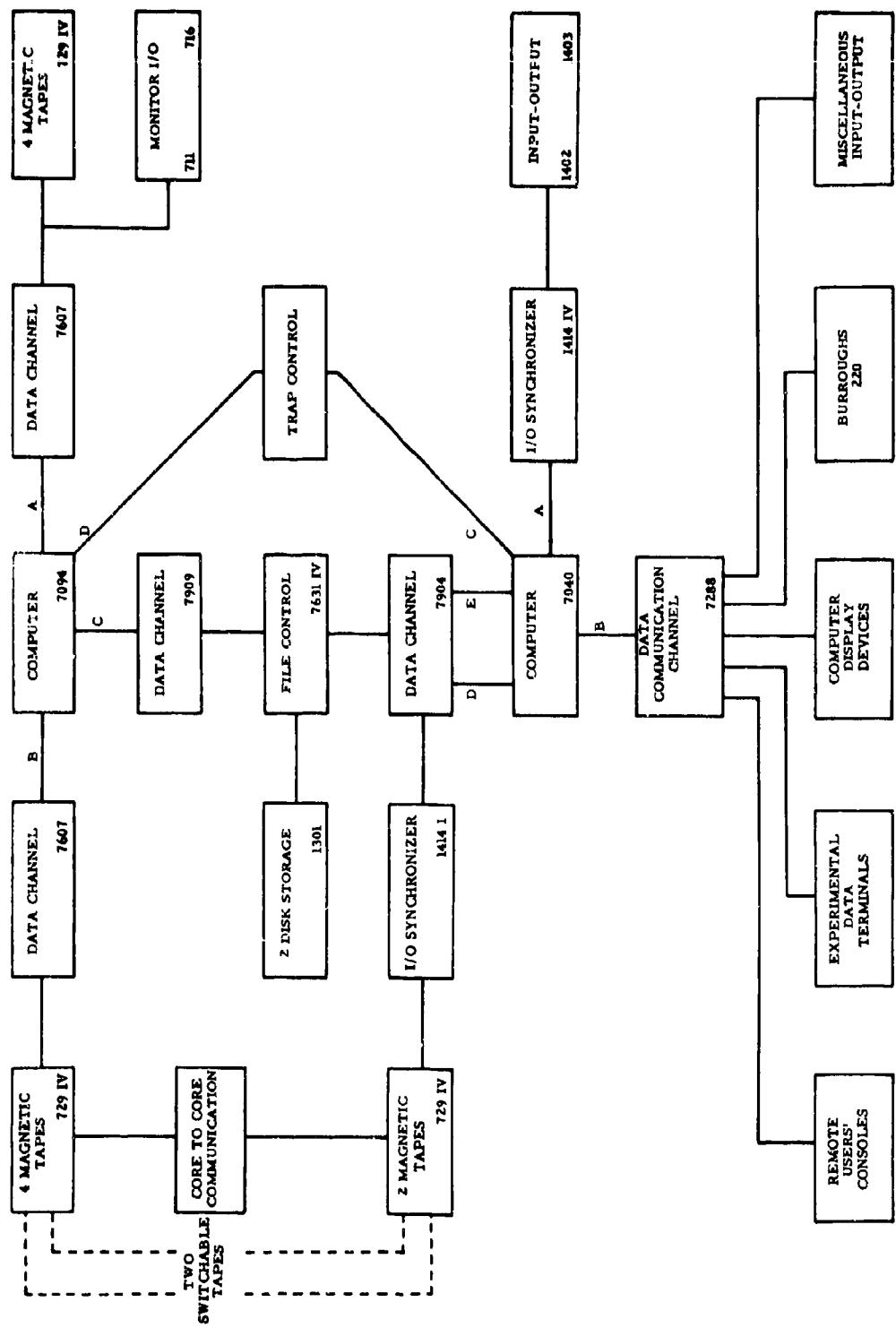


Figure 1.--Schematic diagram of the CIT information processing system

added to provide the multiplicity of characteristics required.

The governing principle which dictated this particular configuration of hardware was the decision that the 7040 must handle all of the communication with the outside environment and the 7094 must be isolated to maintain a high degree of computing efficiency. Conversely, the 7040 is not normally required to handle any appreciable computing load in order to permit it to provide the timely interplexing of a large number of communication channels.

Figure 1 shows the 7094, together with the two 7607 Data Channels and their associated magnetic tapes and monitor I/O equipment which is the "conventional" 7094 hardware configuration. Functionally, however, there are fundamental differences in the utilization of these data channels. In the Caltech system, the 7607 channels are used almost solely for control and monitoring purposes while the 7094 concerns itself almost exclusively with the 1301 disk system which it shares with the 7040. The Input and Output queues (generated by the 7040), the most often used libraries, and the Monitor system all reside on the Disk.

Because of the intimate interaction between the two computers, the sharing of the disk files does not in itself provide a tight enough control link. Consequently two other communication paths have been provided by the Center's engineering staff. The first of these is a trap control capability providing for the initiation of any of the Data Channel D traps in the 7094 by the execution of Channel C tape instructions (which would otherwise never be encountered) in the 7040, and vice versa. The second path between the two central processors provides for core-to-core transfer of data (at tape speed) via the tape channels of the 7094 and 7040. This channel is primarily used for the transmission of timely control information (such as up-to-date disk maps) rather than for large volumes of data or programs.

Two of the 7094's Channel B tapes are manually switchable to the 7040. These are typically utilized when raw test data, recorded on tape by the 7040 is subsequently processed by the 7090.

The primary stream of job input and output is handled in the usual manner by a 1402 Reader-Punch and a 1403 Printer attached in this case to Channel A of the 7040. Some error analysis and proofreading is performed by the 7040 which assigns appropriate priorities to the

incoming jobs and transmits them to the appropriate queues on the disk.

The requirement to tie the system directly to the experimentalist and to place a control capability in the hands of the remote user is satisfied by employing an IBM 7288 Data Communication Channel with appropriate terminal equipment. A great deal of importance is attached to the attempt, in all cases, to tailor the terminal to the needs of the particular human users utilizing it rather than to provide a general purpose input-output device. This approach solves two important problems. In the first instance, it allows the computer to become a convenient and easily used tool for the non-computer oriented research man, and secondly, it eases the burden on the central system by providing local specialization. Examples of this philosophy are found in the experimental data gathering terminals and in the remote users consoles, and are of enough interest to merit some elaboration.

#### EXPERIMENT CONTROL AND DATA COLLECTION

An important aspect of the program to develop this system has been the correlated work by several of the larger Institute research centers in which developed peripheral system concepts for data collection together with data processing concepts for rapid data analysis to be used also in the control of the experiments. These requirements were carefully integrated with the central system design. The principal research areas engaged in this phase were those of high energy nuclear physics, X-ray crystallography, seismology, and biological systems analysis.

Each scientific discipline tends to develop its own peculiar set of experimental techniques and encounters, as a result, a characteristic class of difficulties which inevitably arises whenever the theoretician experiments in the uncompromising reality of the physical laboratory. Even after succeeding in obtaining the raw data of interest, the scientist is confronted with the immense task of analyzing the results properly. Thus he must separate signal from noise and apply appropriate reduction techniques to obtain, finally, the isolated results sought. This can be illustrated by the research of the Biological Systems Laboratory engaged in the study of information processing in living nervous systems. The basic aim of this research is the development of a more precise understanding of nervous system activity. A

large scale computer directly connected to a group of nervous system experiments was considered essential to the development of more precise and complex research. Figure 2 is the systems interconnection, and Fig. 3 is the schematic diagram of the peripheral data processing system for this biological system research.

This work is concentrating on sight perception utilizing a variety of biological systems.<sup>1</sup> In every case the input is a visual stimulus, but the outputs take a variety of forms; eye movement, electrical potential generated by a nerve, torque generated by the system responding to the stimulus, and so on; however, there developed a common group of requirements which had to be met by the instrumentation to permit this discipline to carry on its experimentation in a meaningful and efficient manner. These needs can be briefly summarized as follows:

1. The input, a visual stimulus, is usually a complex function of both time and space, and must be carefully synchronized.
2. The very poor signal-noise ratio which occurs in the output of certain of the experiments dictates that the experiment be repeated many times over in a rapid efficient manner to generate data suitable for averaging, autocorrelation, and Fourier analysis.
3. The physical impossibility of recording the electrical output of a single nerve fiber results in the generation of a multi-fiber record which must subsequently be sorted by application of an amplitude criterion.
4. The objectives of many of the experiments may only be reasonably realized if intermediate results from the analysis of the initial steps of the experiment are available immediately to guide the further course of the investigation.
5. The nature of nervous system investigations often requires that the relative time of a reaction be recorded rather than its amplitude or frequency characteristics.

A rather elaborate, remote data collecting and control system was developed by the Center to link this research group to the central computing facility. In an attempt to solve some of

<sup>1</sup>McCann, G. D. and Ray, C. R. "Computers and Data Processing for Nervous System Research." *IEEE Transaction on Bio-Medical Electronics*, Vol. BME-10, No. 2, April, 1963, p. 48.

the problems just mentioned, the remote system provides the following capabilities:

1. Several precise and variable timing signals are fed to each experimental site for the control of complex input stimuli and for general synchronization purposes.
2. The live test data (almost always in analog form) may be recorded on analog tape or digitized and sent immediately to the computer for analysis.
3. A remote XY recorder and console are available for rapid turn around from the computer.
4. Test data may be selected or rejected locally for analysis by the system based on such criteria as analog frequency or amplitude.
5. The time of an event may be transmitted to the computer rather than a digitized sampling of the event's waveform. The event can be required to satisfy a variety of criteria before being accepted as legitimate.

Thus, the local specialization built into the remote station eases the task of the central system in providing adequate analysis capability.

#### REMOTE USER CONSOLES

These consoles are an attempt to solve the classic problem of large systems utilization, namely, effective and timely communication between the user and the machine. Ideally the computer should possess the availability and ease of operation of a slide rule. Classically, however, its use requires strict adherence to a rigid time schedule and inflexible language rules. The addition of these devices permits an unscheduled flexible utilization of the computing system with timely responses to users' inquiries. Typical uses of the Console are represented by the following:

#### Production Run Requests

The user may request that a program, previously written and stored in the users' library, be inserted into the production queue. Obviously, unless he possesses some special priority, he must wait his turn for execution; however, the Console Monitor in the 7040 will converse with him concerning the status of his request and will permit the introduction of new parameters for his program from his console. The program

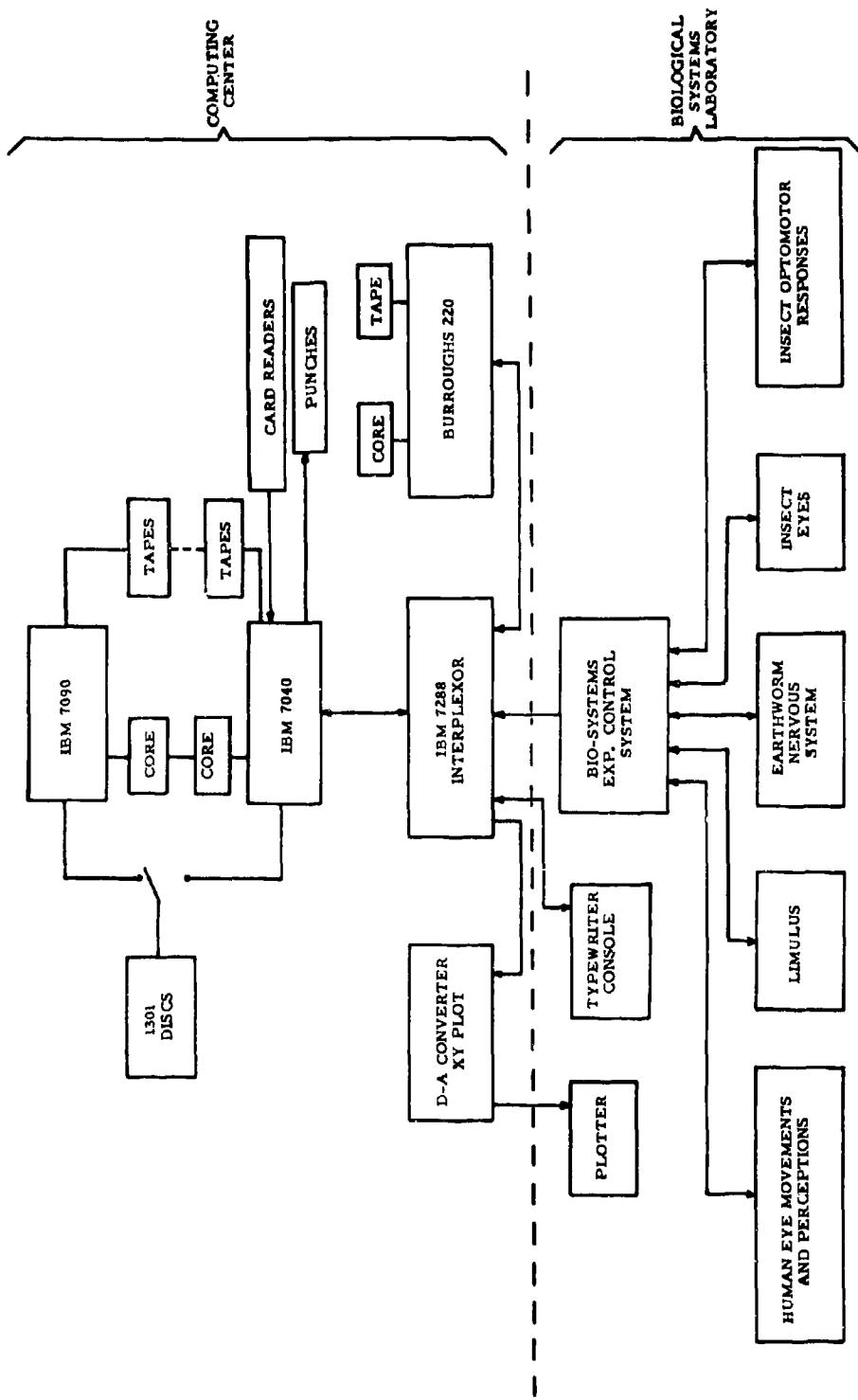


Figure 2.—Schematic diagram of the biological control and data processing system.  
Interconnection of remote experimental data system and central computing facility

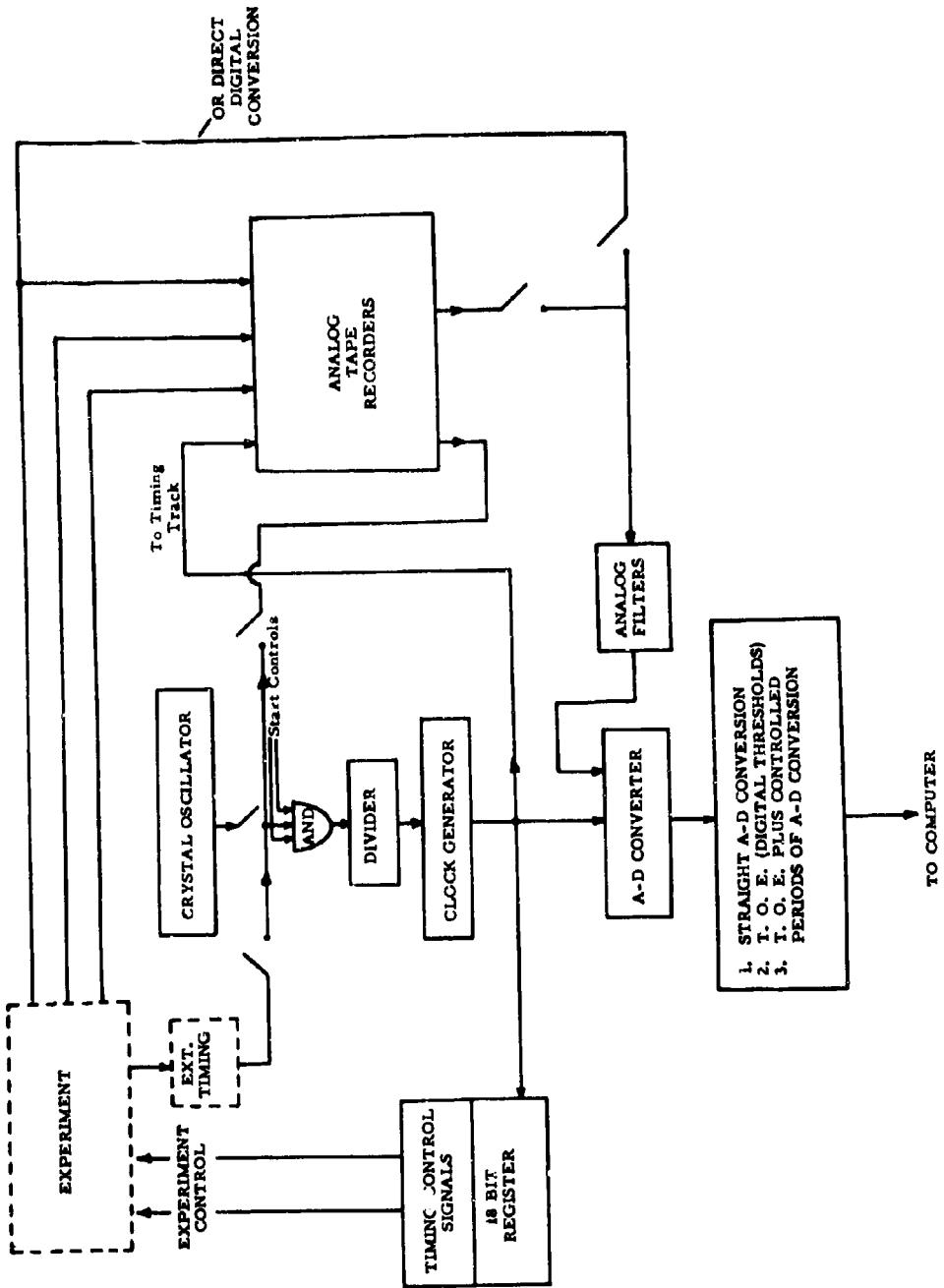


Figure 3.—Schematic diagram of the biological control and data processing system:  
 Functional diagram of main experimental control and data collection system

itself may originate from the console, although unless it is reasonably short this is an unlikely possibility due to the slow transmission rate of the console (typewriter speed).

#### Translation Activities

The user may be involved in constructing a program utilizing some source language, such as FORTRAN, LISP, or the like. In this event, he can enter his statements via the console and the 7040 Monitor will collect them until completed when the user may request a compiler run. Diagnostic statements concerning the status of the compilation and the degree of its success are transmitted to the user.

#### Testing and Debugging

The Users' Consoles are ideally suited to testing and debugging operations since they include activities which require communication between the user and the computer. Thus, the user is able to update an existing program, receive diagnostic statements concerning program status, receive intermediate results, or request a core dump at the central processor. Once a program is completed, the user may request that it be recorded in a users' library for easy reference.

#### Control Data Collection

The user may initiate the loading of a real time data collection program into the 7040 for control of the collection of experimental data being transmitted directly to the computing facility. Intermediate results from data reduction and calibration runs may be immediately transmitted back to the user via the Console.

The Users' Console, then, is an attempt to decrease throughput time. It can activate any of the systems functions in much the same manner that the operator at the control processor does with his control cards. The user, while he enjoys no special priority over other remote users, can "converse" with the system on an unscheduled basis and can bypass the most serious delays classically caused by central I/O limitations.

In an attempt to make life easier for the human being who is using the typewriter of the console, a number of human engineered features have been incorporated. Thus, for example, error correction has been made trivial in that character, line, or message delete action may

be initiated simply by pushing a button. Many illogical human actions such as shifting the typewriter case twice in a row are blocked by the hardware from transmitting nonsensical data to the processor.

The hardware configuration of Fig. 1 might be summarily described, therefore, as an isolated high speed central processor, coupled to a powerful communications center which extends to many remote locations where substantial local data processing occurs. With this introduction to the system's configuration as background, a presentation of the programmed control system follows.

#### PROGRAMMED CONTROL SYSTEMS

The development of the programmed control system for the computing facility resolved into selecting two monitors with very specific characteristics. In the case of the 7094, the requirements dictated a flexible input-output structure and the ability to incorporate major, independent programmed systems under a master, basic monitor. The emphasis for the 7040 system was on communication and a high degree of multiplexing capability.

The 7094 problem was solved by selecting IBM's IBSYS-IBJOB system and rewriting those portions which were required to operate satisfactorily with a shared file configuration. The considerable flexibility provided by IOCS (the input-output control system of IBSYS) satisfied the original specification for variety in input-output capability. Thus the user may choose a printer, a remote console, an XY recorder, a card punch, a magnetic tape, or any future device, for readily producing output through the utilization of a standard output statement.

The other big advantage offered by IBSYS is its ability to absorb large, independent, programmed systems under its control. Mention was made earlier of the need for specialization in peripheral hardware to provide efficient utilization of the computing facility. Similarly, the data reduction techniques and computing requirements of a particular scientific discipline may in some cases be so sophisticated and complicated to warrant the writing of a customized system to serve the specialized needs of the research involved. Thus in the case of the crystallography research at this Institute, an independent system labelled CRYM has been incorporated under IBSYS to serve the needs of the Chemistry department. By this technique, the tedious

assembling of large numbers of complicated subroutines and programs has been eliminated by permitting a higher level of macro designation. In the same manner, other autonomous systems have been added to the facility. Two examples are XMAP, a 7040 assembler and Bell Labs BLODI system. It is of course feasible to add other programs as required, such as the nonalgebraic languages, and so on.

The unique responsibilities assigned to the 7040 required the writing of an original monitor, produced by the Computing Center staff, and labelled CITSYS. This system handles all input and output, and controls the configuration of information on the disk. Jobs are entered either from the card reader or from a remote console (logically there is no difference, a characteristic deliberately included in CITSYS to avoid prejudicing the remote user). Well over 90 percent of all problems submitted by Institute users are written in the Fortran IV language and these are preprocessed in the 7040 by a Fortran Proof Reader which detects about 60 percent of the source errors committed. Assuming the program survives these initial tests, it is assigned a high or low priority based solely on estimated execution time as supplied by the user (the current demarcation time is 1 minute), and placed in the appropriate input queue on the disk. If the entered job is a high priority one which was originated at a remote console, it is placed at the head of the high priority queue (but behind other remote console jobs which may be waiting). The 7040 then traps the 7094 and informs it of the latest disk status including current input and output assignments. Conversely, the 7040 is periodically trapped by the 7094 to establish up-to-date information on the output queues being generated by the 7094.

A low priority job being executed by the 7094 will in every case be interrupted and its status preserved in toto, as long as there is a high priority job waiting to be executed. Computation of the low priority job is automatically resumed when the high priority queue is empty. High priority jobs are never interrupted.

Another useful feature provided by CITSYS is the maintenance of a Test and Production File on the disk. Users may file often used programs in either source or absolute form in reserved areas. Subsequently, through the use of convenient and trivial control statements, the program may be initiated, altered, deleted, debugged, or manipulated in any desired manner. This capability is particularly useful at this Institute where many problems consist

of performing the identical calculation day after day on a variety of input parameters.

CITSYS also provides the facility for including option programs to be run in the 7040 under its monitoring control. The most usual application of this feature occurs in data collecting activities where a typical user requires the 7040 to collect and record experimental test data on magnetic tape under direction of control statements sent via a remote console.

## PERFORMANCE CAPABILITIES

This system has been in operation since November 1963, and there has been ample opportunity to evaluate its performance characteristics. Its advantages to the Institute can be described from several standpoints; one of these is the increased capacity of the 7094 itself.

In order to gain an appreciation of the high degree of computing efficiency achieved by the philosophy described above, a comparison of performance was made against other configurations. In one test, the Caltech system was compared (before its 7090 was converted to a 7094) against a 7094 system where the IBSYS-IBJOB (version 8) standard operating system resided on the 1301 disk and input-output was via magnetic tape. A typical run of 27 FORTRAN IV jobs with the list option required about 16 percent less time on the Caltech configuration (25.41 vs 21.40 min.). With a 7094 in our system, there is a two to one factor in favor of the CIT system.

Another comparison was made against an IBM 7094-7040 direct coupled system now developed by IBM. (Here again, the test was made with the Caltech 7090-7040 combination prior to conversion.) A set of 17 jobs consisting of FORTRAN IV, MAP, and binary decks took 13.15 minutes on the IBM configuration, and 13.25 minutes on the Caltech system. This also shows a substantial gain in basic data processing capacity with our new system.

A second important functional advantage gained by this system is its experimental data collection capacity. Under the most stringent conditions in controlling the 7094, the 7040 only uses 60 percent of its processing time and 18,000 words of its core memory. It has, therefore, provision for sophisticated modes of direct communication with the remote station. For example an average of 180,000 characters per second of experiment data can be collected continuously with substantial peak increases.

One of the most important advantages of this system is the rapid turn around times it provides together with its capability for real time interaction with the remote stations. The distinct differentiation of functions assigned to the two processors, together with the carefully integrated programmed control system provided for each calculator, and the intimate communication links connecting them, has produced an extremely efficient computing facility which possesses the rapid response to demands so necessary to a successful interplay with remote stations. On a communication language level the system responds practically

instantaneously to all remote stations. Experimental data can be collected at any time from many stations. With a maximum unit job time of 1 minute allowed in the 7094, maximum turn around times of only a few minutes are currently being experienced. In this connection it is interesting to note that 80 percent of the jobs submitted require less than 30 seconds on the 7094.

It is not intended that this be the only control system under which we operate. Several research projects occasionally require large blocks of central processing time. These are accommodated during special scheduled periods.

#### Time Sharing Programming Research

Western Data Processing Center  
University of California, Los Angeles  
Los Angeles, California 90024

Western Data Processing Center at UCLA is engaged in fundamental research in programming systems and techniques under Advanced Research Project Agency (ARPA) Contract SD-184, "Computer Network and Time Sharing Research." Work currently in progress includes: investigations of intra-job parallel processing which will attempt to produce quantitative evaluations of component utilization; the increase in complexity of the task of programming; and the feasibility of compilers which perform the analysis necessary to convert sequential programs into parallel-path programs. In order to pursue this study, a simulation is being implemented of a multiprocessor which consists primarily of six CPU's and one core memory. Investigations in storage allocation techniques including dynamic program and data relocation techniques. This study will attempt to produce a family of techniques which explore the effects of multicomputer networks, multi-processors, time sharing, and character addressing machines on the problems of storage allocation. Also under way is the development of programming systems for the hardware configuration at WDPC which currently includes a 7040-7094 Direct Coupled System and an attached IBM 7740 (Communications Control Computer) which services 4 high speed Teleprocessing lines and 12 low speed lines.

#### NEW MACHINES, AUXILIARY EQUIPMENT, AND COMPONENTS

##### 7040-7094:

###### New equipment:

(1)-7320 Drum Storage - 0.8 microseconds per bit; 1,118,400 character capacity; 8.5 milliseconds access (average).

(1)-7740 Communication Control System - 65 K characters of storage; 40 microseconds/instruction;  
4 high-speed lines, 250 characters per second, dial-in lines.  
8 low-speed lines for 1050's (University lines).  
4 low-speed lines for dial-up.  
(2)-1311 Disk Storage Drives - 2.98 characters per pack; direct seek access 140 milliseconds; transfer rate 72 KC.  
(8)-1051-1052 Remote Inquiry Type-writers - 14.8 characters per second  
(4)-1051-1052-1056 Remote Inquiry Typewriters with Card Readers - 14.8 characters per second

##### 1620:

(1)-1311 Disk Storage Drive - 2 million characters, access 250 milliseconds, transfer 72 KC.  
(1)-1626 Plotter Control, 1627 Plotter - Plotting area 11 inches  $\times$  120 feet; 1/100-inch incremental step size, 18,000 steps/minute.

#### PERSONNEL CHANGES

Professor R. Clay Sprowls, formerly Assistant Director and Acting Director during the academic year 1963-64, became Director effective July 1, 1964. Mr. C. A. Irvine is currently Chief of the Center's Programming Staff and Mr. William P. Anderson heads the installation's computer operations, under the title, "Chief of User Services".

## Multi-Computer DP System for Navy Command and Control Center

*Control Data Corporation  
Minneapolis 20, Minnesota*

Control Data Corporation has announced the installation and acceptance by the U.S. Navy of a large complex of computers and peripheral equipment, considered to be the largest ever integrated into a single data processing installation in the history of the Navy. Consisting of over 100 separate data processing devices, this System will be operated by the Navy in support of Command and Control activities of a major complex of Navy and Navy-supported Commanders. Total cost of the system, including provisions for engineering design and development, installation, maintenance, and training is approximately \$15 million.

Nine general-purpose computers form the heart of the Command and Control Center Data Processing System. Operated from a single Central Control Console, these computers are connected to a large number and variety of peripheral devices through a large unique switching network developed by Control Data under the technical guidance of the Navy Department's Bureau of Ships.

Four CONTROL DATA 1604-A computers comprise the large-scale facilities for major information processing and computational tasks. Five CONTROL DATA 160-A computers are used to perform smaller data processing operations and to provide centralized systems control. Peripheral equipment used in the System include high-speed magnetic tape units, disk files for mass storage, high- and low-speed printers, card readers and punches, remote paper tape inquiry stations, and inter-computer units.

The switching network, called the Sub-System Selection Switch, is a specially developed device controlled by a computer program and designed to permit automatic and

completely flexible selection and interconnection of computers and peripheral equipment and/or computers and computers. For example, any of the nine computers can communicate with any other; the switching network also enables any of the nine computers to communicate with any of the dozens of peripheral devices. In addition to the automatic switching features, manual control of the switching is also provided.

The command and control application for which the System is designed characteristically involves a broad variety of computational and data processing tasks. Under certain conditions it is mandatory that several specific tasks of differing complexity but equal priority be processed simultaneously. For this reason, the unique switching concept was developed to permit automatic and rapid organization of sub-systems within the System to provide the necessary redundancy and simultaneity. This approach also permits the problem analyst to design computer programs for the most efficient equipment configuration. For example, rather than attempt to fit a computer program to a rigid, fixed system, he can essentially tailor the System to meet his specific data handling, and computational requirements. Thus, the flexibility provided in this recently installed System is considered to be unparalleled in the history of computing.

A major factor influencing the engineering design of the System was the close schedule for complete implementation of the program, which included engineering, fabrication, installation, and acceptance. Only slightly more than 2 years were allowed from the establishment of firm systems specifications to complete integration and operation of this data processing system, the largest and most flexible complex of integrated computer systems ever installed in a single site.

## Mission and Objectives

*The National Center for Atmospheric Research  
Boulder, Colorado*

The National Center for Atmospheric Research (NCAR) is a basic research establishment dedicated to the advancement of the atmospheric sciences for the benefit of mankind.

The perspectives and the scientific activities of NCAR are those of a research laboratory devoted to achieving a fundamental understanding

of natural phenomena. The scientists in NCAR recognize, nonetheless, that the public funds on which NCAR operates are given in anticipation of public benefit, and they acknowledge an obligation to organize their research with a view towards such ultimate benefits, and to cooperate with other agencies in achieving them.

NCAR pursues its goals through the conduct of basic research and through cooperative planning and operation of joint research and facilities programs. These are designed to assist and to extend the atmospheric research and educational efforts of the universities and other research agencies of the nation.

The specific means by which the staff of NCAR seeks to achieve its objectives may be listed as follows:

1. By creating within NCAR a broadly based, interdisciplinary research center whose functions are to pursue the fundamental understanding of atmospheric processes, to encourage post-doctoral education, and to attract talented students to the atmospheric sciences;
2. By serving as a research and facility planning center to aid the development of large-scale research programs involving a number of institutions, or to bring about the creation, under NCAR auspices or otherwise, of needed major facilities for use by several institutions jointly; and
3. By managing and operating joint-use facilities, generally in response to the university community, where clearly established national interest dictates, and where no other institution is in a position to provide such facilities more efficiently.

#### THE FACILITIES DIVISION MISSION

In accord with the mission of NCAR, the objective of the Facilities Division are: (1) to plan, establish, and operate support facilities, both at the Center and in the field, which are required to support the scientific program of NCAR, but which are not appropriately administered by an individual program; (2) to plan, establish, and operate large-scale facilities, both at the Center and in the field, which are required to meet specific research needs common to a large segment of the scientific community and which can be most effectively provided through NCAR; (3) to conduct development projects intended to provide desired new techniques and systems for the field observation of atmospheric variables; and (4) to conduct technical assistance and information exchange programs designed to keep atmospheric scientists, both within NCAR and at large, advised as to the most advanced techniques available and as to the characteristics and availability of existing research facilities within the United States and abroad.

Because the aim of the NCAR facilities program is exclusively to serve the research needs of working scientists, the design, operation and continuing review of facilities programs must be responsive in detail to the rapidly changing problems and requirements of atmospheric research both within NCAR and among members of the scientific community at large.

#### THE NCAR COMPUTING FACILITY MISSION

The NCAR Computing Facility will support scientific and facilities programs by both NCAR and non-NCAR users by providing computing services and advice. NCAR identifies four categories of users: (1) NCAR users—persons working at NCAR either as employees or as visiting scientists; (2) cost-free non-NCAR, NCAR mission related users—persons engaged in the atmospheric sciences, not working at NCAR, whose problems are approved by the Panel for solution on the NCAR computer without charge; (3) paying non-NCAR, NCAR mission related users—persons engaged in the atmospheric sciences, not working at NCAR, whose problems are approved by the Panel for solution on the NCAR computer subject to payment of the costs of computation; (4) paying non-NCAR mission related users—persons not working in the atmospheric sciences whose problems are accepted for solution on the NCAR computer during otherwise unscheduled time, subject to payment of the costs of computation. These users must represent a non-profit institution.

For NCAR users, the Facility will either program problems presented to it or assist the scientist in programming them. It will give advice to all users and, whenever possible, programming aid to cost-free non-NCAR users. It will keep itself advised of the progress of the cost-free non-NCAR users programs so as to be able to report their current status to the Computing Facility Panel.

It will instigate investigations into the mathematical aspects of computing problems relating to the atmospheric sciences.

It will identify requirements for computing services within NCAR and, with Panel assistance and concurrence, for computing services within the atmospheric sciences outside NCAR which cannot be readily fulfilled by other computing centers. It will obtain equipment and obtain or develop the personnel to meet these requirements.

### **BRLESC Memory Improvement**

*U.S. Army Ballistic Research Laboratories  
Aberdeen Proving Ground, Maryland*

A major improvement to the BRLESC (Ballistic Research Laboratories Electronic Scientific Computer) was completed in June with the installation of 49,152 additional words of high-speed memory. The memory actually consists of three independent units of 16,384 words each, with 72 bits per word and a complete read-restore or clear-write cycle time of 1 microsecond. The memory, which was built by the Ampex Corporation, permits many gains in operating efficiency by (1) improving basic machine speed in many "short" instructions

since the machine was designed for a memory cycle time of 1 microsecond, but it has been operating heretofore with essentially a 2-microsecond memory; and (2) since the "old" memory was only 4096 words, many programming improvements can now be made with the greatly increased capacity. One of the most important advantages of the increased memory capacity is BRLESC's ability to accommodate a much wider class of FORTRAN II programs. These were previously gravely limited by the small 4096-word memory.

### **Computation Center**

*U.S. Naval Weapons Laboratory  
Dahlgren, Virginia*

The new building for the Computation and Analysis Laboratory includes spaces specially designed for computer installation as well as offices for laboratory personnel. All computing facilities of this laboratory are being moved except the NORC, which will continue to operate in the old building.

Recent developments in software include:

**STRETCH (IBM-7030)**—A new compiler for FORTRAN IV has recently been provided by IBM. This compiles about 17 times faster than did the previous version, and yields

object code which runs approximately 5 percent faster.

A debug package similar to that available under IBSYS on the 7090/94 has been developed at NWL and is now operational. Instructions for using this system are available in the STRETCH Procedures Manual published at NWL.

**NORC (Naval Ordnance Research Calculator)**—NORCTRAN, a version of FORTRAN IV for the NORC, is in use on a limited scale. The entire system is expected to be operational shortly. A technical memorandum describing this system is in preparation.

### **LARC System Performance Data**

*U.S. Navy David Taylor Model Basin  
Washington 7, D.C.*

During the fiscal year 1964, the LARC II System performance was 96 percent. This higher performance percentage was the direct result of an improved preventive maintenance program and of the maintenance personnel's ability to perform corrective maintenance quickly.

By referring to Table 1 it can be seen that by reducing the Total No. of Interruptions, the Down Time was drastically reduced while the Mean Free Error Time was increased by a significant factor.

All of the file drums on the LARC II System have recently been modified by installing an improved type head stepping motor. A life test on the new motor was run by installing one of the motors in Drum #9 in February 1963. After 15 months of operation the motor was still operating satisfactorily. Based on the results of this test new motors were installed in all 12 drums. Inasmuch as the drum motors caused an appreciable amount of the Down Time in 1964 it is felt that, barring unforeseen difficulties, it should be possible to maintain the Performance Percentage at approximately 97 percent.

Table I  
LARC II MONTHLY PERFORMANCE FIGURES

Month	Total ON Time	Productive Time	Down Time	Total No. of Interruptions	Mean Free Error Time	Down Time Per Error	Performance Percentage
Jun 63	418:42	301:13	32:18	47	6:25	0:05	98.5
Jul 63	370:32	266:57	18:03	44	6:07	0:22	93.8
Aug 63	403:20	295:25	10:48	20	14:45	0:32	96.6
Sep 63	394:23	265:00	15:52	21	12:08	0:45	94.4
Oct 63	335:09	203:54	7:59	16	12:53	0:29	96.4
Nov 63	228:00	122:51	2:01	6	20:28	0:21	98.0
Dec 63	358:03	153:36	8:28	14	10:58	0:36	95.0
Jan 64	357:28	268:43	5:33	18	14:57	0:18	98.0
Feb 64	361:07	275:21	3:25	6	45:53	0:34	98.9
Mar 64	486:56	390:08	10:42	25	15:36	0:25	97.4
Apr 64	310:39	199:21	6:43	11	18:10	0:36	97.0
May 64	264:43	144:01	7:02	13	11:04	0:31	95.4
Yearly Totals	4190:56	2878:30	128:54	241	15:32	0:28	96.0

Yearly Performance Figures for Fiscal 1962, 1963 and 1964

1962	5069:18	3736:36	462:18	995	3:45	0:28	89.0
1963	5927:32	3630:03	516:45	928	3:54	0:32	87.6
1964	4190:56	2878:30	128:54	241	15:32	0:28	96.0

## Computers and Centers, Overseas

### The Leo-Parnall Autolector

*English Electric-Leo Computers Ltd.  
London W.2, England*

#### INTRODUCTION

The Leo-Parnall Autolector is an automatic optical scanning device which reads both computer printed and hand marked forms directly into a computer. The equipment is coupled on-line and is controlled from the computer.

Two models are available, one for handling small forms, the other for handling large forms.

#### FORMS

The forms should be printed on good quality white paper, preferably 18- or 21-pound large post, and in the following size ranges: the small forms range from 4 by 5 to 6 by 9 inches and the large forms range from 7-1/2 by 9 to 8-1/2 by 16 inches, with the proviso that the length must be at least 25 percent greater than the width. The forms may have perforated or straight edges and may also be punched with sprocket holes along either side.

#### COLUMN AND LINE LAYOUT

Information may be entered on up to 16 columns set at 0.300-inch pitch. Lines may be spaced freely on a form, at a minimum of 1/4-inch separation standard; in more closely controlled conditions lines may be spaced with 1/5- or 1/6-inch separation. The position of each line, and the significant marking area, is defined by a pair of location marks.

#### INFORMATION MARKS

The forms may be marked with black pencil (grades HB, H, or F), by computer printer, and by embossed plate.

A mark is made by joining two points of a marking aid with a horizontal line. A number of different types of marking aids may be used.

Marks are scanned across a width of 1/10 inch in the centre of each column.

A variable two-level discrimination feature distinguishes between 'certain' and 'doubtful' marks.

In preference to erasing any mark made in error a cancel mark is entered by filling in the lower half of the rectangle formed by the line/column grid.

#### SPEED

Forms are processed at a constant rate, irrespective of the data content; the rate for the small form model is 300 forms per minute, and for the large form model is 270 forms per minute.

#### OPERATING SYSTEM

The forms are stacked into portable containers, which are then loaded on to a conveyor: the conveyor may be loaded continuously, without interrupting the free running of the machine.

The forms are selected individually from the containers by a vacuum pick-up and then carried by alignment rollers to the vacuum drum, on which they are held smooth and read.

After reading, the forms are picked off the drum, and passed to the output bin if read or to a re-run bin if the computer has not accepted the information.

Form jam-detecting devices, which automatically stop the machine are fitted throughout the paper handling mechanism; and a double feed check ensures that only one form is fed at a time.

## ZAM-41

Instytut Maszyn Matematycznych  
Warszawa, Poland

ZAM-41 is a medium-size, parallel, high-speed, fully transistorized digital computer. Its elastic structure permits the combination of various computer sets. Depending on the chosen capacity of ferrite storage, input and output devices, drum storage, and magnetic tape units the ZAM-41 may be effectively used for data processing, scientific computations, and control in real time.

### CHARACTERISTICS OF ZAM-41

Basic word length 24 and 48-bits  
Binary arithmetic

24- or 48-bit integer numbers

43-bit floating-point numbers

24-bit one-address instructions encompassing  
64 various operations, direct addressing  
up to 32768 ferrite storage words, indirect  
addressing, and B-modification

Programmed instructions freely defined by the  
programmer

Internal ferrite storage is composed of standard  
blocks containing 4096 or 8192 words,  
maximum capacity 32768 words

Operation times

logical operation	20 $\mu$ sec
fixed-point addition or subtraction	30 $\mu$ sec
fixed-point multiplication	110 $\mu$ sec
floating-point addition	350 $\mu$ sec
floating-point multiplication	850 $\mu$ sec

A possibility of multipriority program interruption

A possibility of executing simultaneously several independent programs fully secured  
against program mutual interference

Elastic block construction

Standard channels for the following peripheral  
devices:

operator's desk with paper tape reader of  
5, 7, or 8 tracks, tape punch, and monitor typewriter  
column card reader  
card punch  
line printer  
drum storage  
magnetic tape storage  
real time channel connecting the computer  
with the controlled object.

By the use of synchronizers, an automatic transfer of data between ferrite and magnetic tape storages is possible while performing computations.

Great reliability of operation is due to the exclusive use of semiconductor and ferrite elements, numerous built-in circuits checking computer operations, and automatic marginal testing.

### MODERN PROGRAMMING SYSTEMS FOR ZAM-41

SAO - Symbolic Addresses and Operations, programming system in computer language

ALGOL & - automatic programming systems  
FORTRAN for numerical problems

COROL - automatic programming system for data processing problems

SOP - operation system enabling an easy and effective computer handling.

The input-output speed is dependent on the type of peripheral device connected to the computer.

### Hybrid Computing Center

Northampton College  
London E.C. 1, England

Northampton College, London, England (shortly to be developed as a University) is expecting delivery of an I.C.T. 1900 in September 1964. This machine will have 32,768 words of 24 bits of core store with a cycle time of 2  $\mu$ s.

The built-in, floating-point arithmetic unit will add and subtract in 12  $\mu$ s, multiply in 28  $\mu$ s, and divide in 47  $\mu$ s. Two paper tape readers will input data at 300 characters per second, the paper tape punch operates at 110 characters

per second (eight-hole tape). The analex line printer prints 1000 lines per minute and the three magnetic tape decks operate at 167,000 characters per second. The machine will be able to process four independent programmes. It is expected that normal programming will be done in the PLAN assembly language, Algol and Fortran.

This machine is being installed as part of a Hybrid computer system to deal with the expansion of work which has taken place since the installation of the Ferranti Pegasus and Elliott G-PAC computers in 1957.

### The Xeronic High-Speed Computer Output Printer

Rank Data Systems  
London W.12, England

#### INTRODUCTION

The earlier model of the Xeronic printer has now been superseded by a model having 32 form selections. A number of these are already installed and others on order in Britain and on the Continent of Europe. On some of these installations the equipments have been working around the clock for considerable periods, with little down time other than for scheduled maintenance including replenishment of the machine consumables.

The elimination of preprinted stationary and the ability to select form backgrounds by programme without loss of printing speed in the printing operation give a major increase in system flexibility and reductions in running costs.

#### GENERAL

The Xeronic high-speed computer output printer utilises xerography and an electronic method of character generation to produce printed forms at a linear paper speed of 40 feet per minute. This speed represents a maximum computer output rate of 4700 characters per second or 2880 lines per minute.

The printer can be used off-line to the computer. The input to Xeronic comes from a magnetic tape on which the computer output has previously been recorded. A small buffer ferrite core store and tape control circuits are included in the control cabinet.

Besides printing characters representing the computer output, the machine also simultaneously prints its own form outlines. The great versatility of the Xeronic printer is due to this unique feature, together with the fact that all its functions are entirely under control of the computer. All commands and information for

operating the printer, including form selection and tabulation instructions, are provided as part of the input to the printer. This allows the programmer considerable freedom in specifying form layouts and permits a change from one type of form to another merely by inserting the form number in the appropriate command; in this way up to 32 form outlines are available for immediate selection without loss of printing speed.

#### CHARACTER GENERATION AND POSITIONING

Characters to be printed are displayed under control of the input data as a pattern of overlapping dots on the face of two cathode-ray tubes. This method of generating visible characters is one which combines accuracy of alignment and clarity of outline with simple and reliable circuitry. The actual character generators are, in fact, passive circuits consisting mainly of resistors on plug-in printed circuit boards. Normally 56 different characters are provided but additional ones up to a maximum of 112 can be supplied.

Positioning circuits ensure that successive characters are printed either in adjacent columns or at specific positions in the line according to the tabulation instruction in the programme.

Special fonts of characters (E13B, etc.) suitable for optical reading equipment can be provided.

#### THE XEROGRAPHIC PRINTER

The disposition of the various parts of the printer is shown in Fig. 1. The selenium forms a thin coating on the surface of a cylinder, known as the xerographic drum. This drum rotates slowly at constant speed and all the

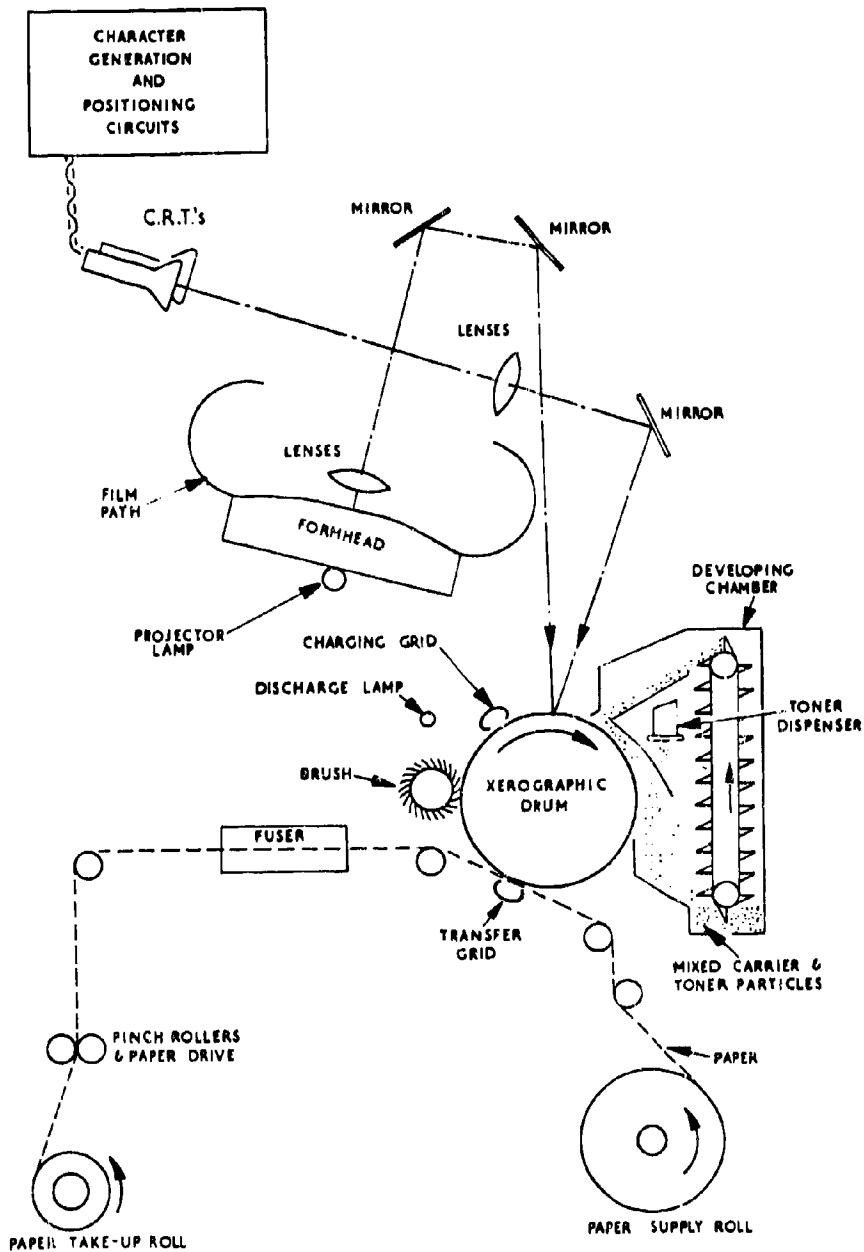


Figure 1.--The xerographic printer

operations necessary to produce the printed image take place around its periphery.

In darkness the selenium surface of the drum passes under a charging grid from which it acquires a positive charge. The charged surface is then exposed to two light sources; one is a pair of cathode-ray tubes on which visible characters corresponding to the computer output appear; the other source is a formhead from which negative photographic masters of form overlays can be projected on to the drum. Those portions of the drum surface that have been exposed to light from either of these two sources, lose their charge but the areas that have received no exposure still retain a positive charge.

The charge pattern on the drum is developed by cascading over it a powder comprising two components. One part, known as the carrier, consists of hard spherical particles about 0.6 mm in diameter; the other part is the toner consisting of coloured particles dispersed in a thermoplastic powder. The toner is the material from which the final image on the paper is formed and the carrier provides the means for distributing the toner over the surface of the drum. These two parts, the carrier and the toner, are intimately mixed and as the particles rub together the toner acquires a positive charge and is attracted to the edges of the uncharged areas of the selenium. The carrier particles, being heavier, roll off the drum and are returned to the developing chamber.

As the drum rotates it comes into contact with paper fed continuously from a roll and the toner is transferred from the drum to the paper by means of a negative charge applied to the paper by a transfer grid. The visible images of the characters formed on the faces of the cathode-ray tubes, together with the superimposed image of the form outline, are thus transferred to the paper. They are rendered permanent in the fusing chamber where the thermo-plastic particles are melted by heat and fused to the paper together with the toner particles forming the visible image. The residual charge on the drum is removed by illumination from the discharge lamp and at the same time a revolving brush removes any remaining particles of toner from the drum.

The roll of paper is cut into sheets in another operation by a separate guillotine which is controlled by registration marks on the form itself.

## THE FORMHEAD

Up to 32 different form outlines can be stored on a length of film, known as a form master. Once the original of the form master has been produced, duplicate films are readily available, and when they become worn or scratched in use they can easily be replaced. If more than 32 form outlines are required, it is the work of only a few minutes to change the masters for films bearing a different set of 32 outlines.

The formhead is a dual unit comprising two similar film-positioning mechanisms side by side; the two form masters are identical and are used alternately, one being printed while the other is being positioned. In this way the next form is ready for printing as soon as the previous form has been completed and no time is wasted in the mechanical process of form selection.

To minimise wear on the master, air is forced between the film and the projection gate whenever a fast drive is engaged, so that the film is supported on an air cushion out of contact with the gate.

## CONTROL OF THE PRINTER

The arrangements for "off-line" working are illustrated in the block schematic diagram of Fig. 2. The core buffer store is used to match the speed of the regular succession of signals from the magnetic tape to the irregular demands of the printer, irregular because of the different layout requirements of each line. The store control ensures, on the one hand, that there is always a character in the store ready to be read out whenever the printer demands it and, on the other hand, that writing in from the magnetic tape unit is halted before the capacity of the store is exceeded.

Both data characters to be printed and commands for the control of the printer are held in the store, but are separated in the decoder and are treated differently. As each printable character is demanded, it is read out from the core store, decoded, and routed to the character generator. At the same time the horizontal address register applies a deflection waveform to the cathode-ray tube to position the character in the correct column.

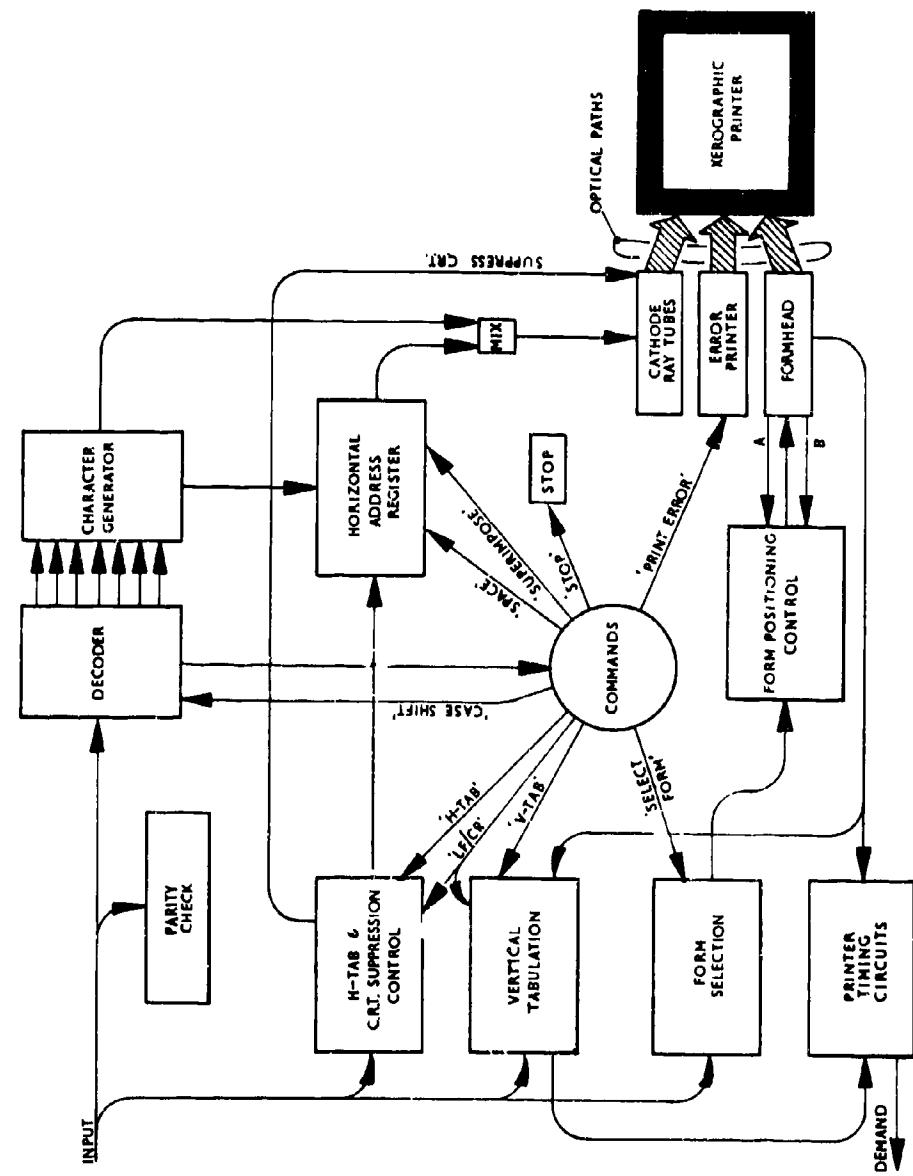


Figure 2.--Block diagram of printer control

Commands are decoded onto separate lines which control the various functions. These commands are:

- SELECT - causes the formhead to print FORM the form outline currently required and to position the master for the next form.
- V-TAB - causes the next printing line to shift to one of the 16 preset vertical tabulation positions.
- H-TAB - causes the next character to appear at the horizontal tabulation position specified in the command; it also controls suppression of the CRT.
- SUPER- IMPOSE - permits two characters to be printed in the same column and is used for underlining.
- LF/CR - indicates the end of a line.
- PRINT ERROR - actuates an error printer which makes a distinguishing mark on the printed form.
- SPACE - inserts a space in the corresponding column.
- STOP - halts the machine at the end of a record or group of forms.
- REPEAT - is used only in the core store and causes a form to be repeated for a selected number of times using the same form data. (Since not all users require this facility, it is not part of the standard machine, but can be provided as an extra.)
- CASE SHIFT - selects the appropriate character generator when more than 56 printable characters are required with a six-bit code.

#### ERROR DETECTION

Adequate checks are made on information entering and leaving the store to ensure that either a printed character is correct or, if incorrect, the erroneous form is clearly marked as such.

Information read from the tape includes lateral and longitudinal parity checks. If a

check fails, a "Print Error" command is inserted into the store so that an error mark will be included on the erroneous form when it is eventually printed. The lateral parity is retained in the store and permits the character to be checked once again when it is read out to the decoder. If, after this point, a component or connection fails in the character generator or cathode-ray tube supply units, either a character will lose only a fraction of its legibility through the loss of one or two dots, or a character will fail to appear at all. To detect the latter occurrence, the voltages applied to the bright-up and deflection circuits of the cathode-ray tubes are monitored and compared with voltages derived from those parts of the logics which determine whether a character is to be displayed or not. If the two do not correspond, an error mark is printed on the form and if the fault is one likely to cause damage to the tubes, the E.H.T. is automatically switched off.

Other monitoring circuits check that certain essential commands have been read in at the right time and that the formhead is receiving the correct succession of control signals. The nature of an error is indicated by lamps on the control panel and automatic stopping of the machine may be initiated by selected error or interlock failure signals according to the customer's requirements.

#### LAYOUT OF FORMS

Printing takes place on a continuously moving web of plain paper, 26 inches wide. The characters to be printed are formed in duplicate on the two cathode-ray tubes, which are supplied with common deflection waveforms so that two lines, each 11-1/2 inches wide, are printed side by side. Each line has a total of 128 character positions and the printing on one half of the web is normally duplicated on the other half, producing two forms at a time, one an exact copy of the other. Both cathode-ray tubes can be blanked out or the display on one tube can be suppressed independently of the other, a facility which allows information to be omitted from positions on either or both forms under control of the 'h-tab' command.

The formhead contains the masters for 32 6-inch forms, although longer forms up to 18 inches in depth can be used with a consequent reduction in the number available for selection.

Included on the form master, but not printed, are registration marks which are sensed by photocells in the formhead and used to control the printing of the lines of characters.

When one of the 16 vertical tabulation points are selected by means of a 'v' tab order, printing cannot take place until the appropriate registration mark is sensed by the photocell. In this way, line and vertical tabulation positions are determined by the form itself and consequently accurate registration (within 0.05 in.) is achieved between the form outline and the variable printing on it.

Great trouble was taken in the design of the cathode-ray tube deflection system to ensure that no character was displaced from its nominal horizontal position with reference to the form by more than 0.05 inch. In addition, the error in spacing between adjacent characters in a line does not exceed 0.005 inch.

#### CONSTRUCTION

The equipment comprises four separate units:

The xerographic printer.

The auxiliaries unit containing the dust extractor, formhead lamp control gear, and formhead air pumps.

Electronic control cabinets.

Paper cutter, including reel holder and form stacker.

The control cabinet need not be adjacent to the printer, but can be connected to it by up to 50 feet of cable. The auxiliaries unit can be up to 20 feet away from the printer. Test equipment is available.

#### COST

Because plain, unprinted paper is normally used, the running costs of the machine are low. Naturally the actual figure depends on the type of paper employed, but for business use the cost of paper and all xerographic consumables (such as toner, cleaning materials, lamps, cathode-ray tubes, formhead masters and xerographic drum) compares favourably with the cost of any other printing system.

#### MAINTENANCE

It is realised that a fault which necessitates the printer being out of use for even a short period, can be the source of much inconvenience and annoyance to user. Consequently,

every effort has been made to ensure that the 'down time' due to faults is as little as possible. Engineer's monitoring facilities are built in and all circuit units are constructed on plug-in boards which can be quickly replaced. Transistors are used throughout.

#### PAPER CUTTER

The high operating speed makes it essential to use a comparable machine for handling the large output of paper that comes from the printer. This has not been neglected and a high-speed cutter in which the actual position of the cut is determined by marks printed on the form, is provided as part of the equipment.

Vertical perforations can be made in the paper just before it is spooled up on the printer and at the same time the margins of the paper are trimmed.

#### ABRIDGED SPECIFICATIONS

Paper Speed: 40 feet per minute (8 inches per second)

Printing Speed: 4700 characters per second maximum, 2800 lines per minute at a spacing of six lines to the inch

Paper Width: 26 inches maximum

Form Size: 24 inches wide x 18 inches long maximum

Line Width: 2 x 128 character positions or 2 x 114 character positions according to character size

Character Size: Approximately 11 characters per inch or 10 characters per inch according to requirement

Line Spacing: Unrestricted provided that it is not less than 1/6 inch

Characters Available: 56 alpha-numeric as standard. Up to 112 as an extra

Tabulation: Any horizontal column and 16 vertical tabulation points can be selected

Selective Printing: Information can be suppressed on either or both cathode-ray tubes

Formhead: Up to 32 forms available for automatic selection

**Input:** 6, 7, or 8 bit code to customer's requirements

**Paper Cutter:** Will cut and stack lengths from 3 inches to 18 inches under control of photo-electrically sensed cutting marks

**Paper Perforators:** Four fitted, together with two edge trimmers

**Paper Reel Size:** 12-inch maximum outside diameter on a 2-3/4-inch core (approximately 2000 feet of average thickness paper)

**Power Supply:** 415 volts, 3 phase, 50 cycles per second. Other supplies to order

**Power Consumption:** Approximately 12 kVA

**Store Capacity:** 1024-character store is standard. Larger stores can be supplied as necessary.

## Miscellaneous

### Man-Machine Communications and On-Line Computing

*The Bunker-Ramo Corporation  
Canoga Park, California*

Though it may be some time before computers can be made to respond simply and directly to spoken queries or commands addressed to them at random, research at The Bunker-Ramo Corporation has gone far toward improving the way in which computers and their users communicate with each other. Through the parallel development of on-line computing techniques and man-machine communication consoles, the Company has made it possible to bypass the cumbersome procedures of conventional computer operations and enabled persons in widely differing fields to use a computer directly and extemporaneously.

Solving problems with the usual computer procedures involves:

- Thorough analysis of the problem requirements and method of solution.
- Imparting this knowledge to a computer programmer.
- Waiting for the problem to be programmed.
- Waiting for the answers to be delivered from the computer center.
- Waiting for the problem to be reprogrammed because it turns out that it wasn't possible after all to completely anticipate the problem structure or correct method of solution.

By contrast, properly implemented on-line computing techniques enable:

- Direct, two-way communication between computer and the man with a problem to be solved.
- Immediate responses from the computer.

- Continuous control by the user over the computer.
- Ability to compose or modify problems solving strategy on the spot, depending on the user's evaluation of partial results during problem solution.

To a great extent, the devising and applying of these techniques has been made possible by the unique properties of a family of communication and control consoles produced by The Bunker-Ramo Corporation. These consoles, of which the 85 Control/Display Console (Figs. 1 and 11) is typical, allow a real-time interaction to take place between computer system and human user, an interaction that is fundamental to the operation of a true man-machine system.

To address the computer, the person at the console's controls simply presses buttons labeled in natural, problem-related terms. The buttons actuate pre-programmed routines that, within milliseconds, causes the computer to reply in the form of tabular, message-type, or pictorial displays on a cathode-ray tube screen (Fig. 2).

The person addressing the computer can be a specialist in a certain field, working on one of many different tasks: a logistics support manager investigating an item's supply history; an air traffic controller talking-in a plane; or a research scientist analyzing a theoretical problem whose structure can only be guessed. One specialty these men do not need is an expert knowledge of computer programming; on-line programming methods allow them to devise their own problem solutions.

A single console keyboard can accommodate a remarkable number of diverse projects. And it can be made to switch from one project to another within seconds. The secret of this versatility lies in a special provision for 64

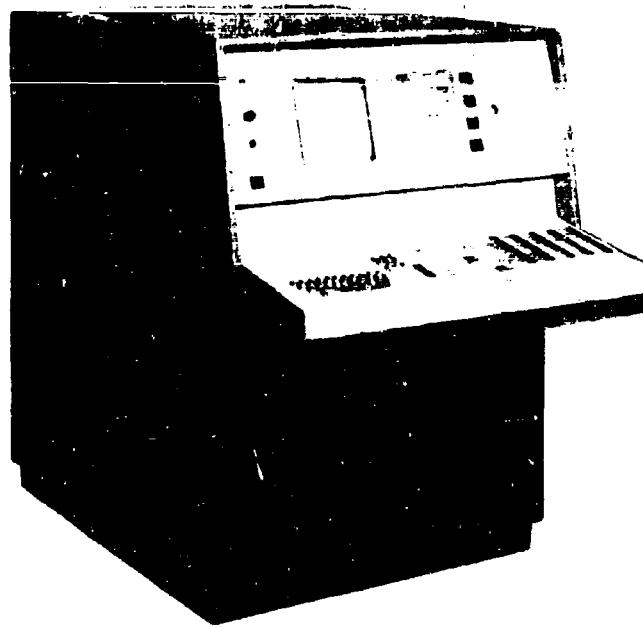


Figure 1.—Computer communication console



Figure 2.—Data displayed in a tabular format

program keyboard overlays (Fig. 3) each of which, when inserted, changes both the labels and the functions associated with the keyboard buttons. A newly inserted overlay links the buttons with a different set of computer programs and so completely reorients the use of the console. One console can thus serve for operations

in logistics and intelligence and scientific computing, or for a great many varied uses within one such category.

These consoles will work with virtually any computing system without monopolizing its normal day-to-day operations.

#### TECHNIQUES IN COMPUTER AUGMENTATION OF HUMAN REASONING

During the past several years, The Bunker-Ramo Corporation has used the computer communication equipment and methods described in these pages, as well as more orthodox computing approaches, as a means of augmenting the powers of human reasoning and of integrating human judgment and intuition with the high-speed problem solving abilities of digital computers. Four of the areas in which Bunker-Ramo has applied these techniques are:

#### Scientific Research Problem Analysis

Here the capabilities of display consoles have been exploited to permit a research scientist to compose his strategy for solving a problem during the computer process itself. That is to say, the scientist at the console can modify



Figure 3.--Program keyboard overlay

whatever approach he has just been using as he sees the results of his push-button directives—attempts at problem solution—presented graphically on the display screen (Figs. 4 and 5). In a recent analysis, for example, of the effects of an external electric field on plasma oscillations, this immediate feedback characteristic (and other benefits of on-line programming) allowed physicists to work out techniques for solving kinetic equations in the time domain and obtain exact solutions for representative cases.

#### Engineering Problem Analysis

Since engineering problems and their solutions are often most easily understood when they are presented in graphic form, Bunker-Ramo communications devices lend themselves particularly well to engineering applications. An example is the investigation of the stability of a servo system. Here, the engineer performing the investigation can use a console and on-line programming techniques to construct a mathematical model of the servo system (Fig. 6), and analyze the effect of varying the functions and parameters of the system (Fig. 7). The results of the computations requested by the engineer may be displayed in a meaningful format he is accustomed to seeing—such as a Nyquist plot, or families of plots, for any number of variables.

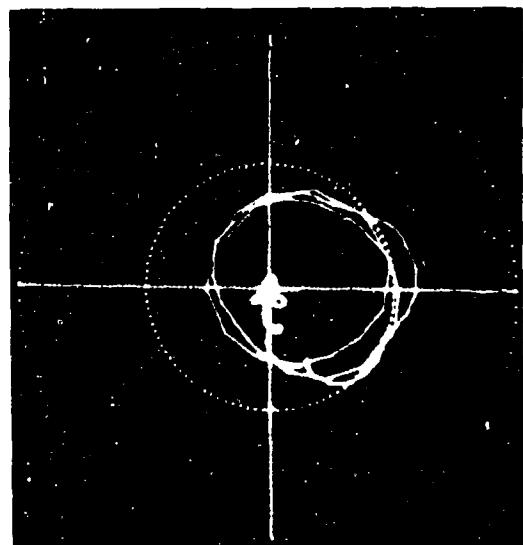


Figure 4. --A numerically generated curve from studies of electrostatic wave fluctuations in an electron-ion plasma

Inasmuch as he can thus directly view the effect of varying system parameters, the engineer can quickly analyze his servo problem.

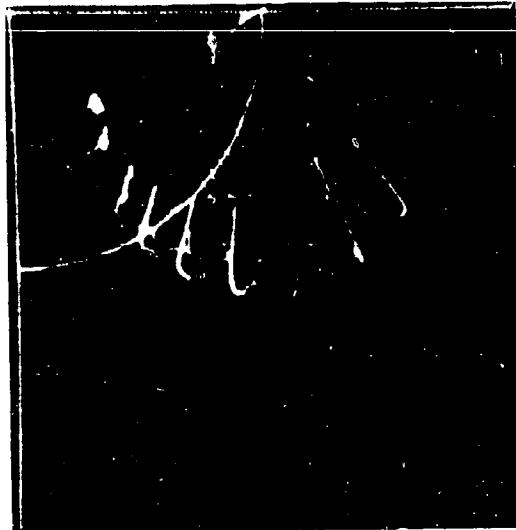


Figure 5.—A numerically generated curve from studies of electrostatic wave fluctuations in an electron-ion plasma



Figure 6.—Nyquist plot of simple servo

#### Command and Control Problem Analysis

In military command and control applications, Bunker-Ramo has found that its computer communication consoles and on-line programming techniques can materially improve the effectiveness of command staffs. In these situations, the ability of a computer to calculate at high speeds, and select and present data derived from an



Figure 7.—Nyquist plot of same servo with a sampler added



Figure 8.—Line drawings on display screen can give a better understanding of many situations

extensive data base, is used to complement the human ability to postulate alternative solutions to a given problem. The commander exploits his own background and experience in formulating possible solutions; the console enables him to exploit the computer's capacity for rapidly processing information (Fig. 8), and he can evaluate in quick succession the effects of any one of his possible decisions.

#### Information Analysis

An example of computer augmentation of human reasoning with conventional equipment is

Bunker-Ramo's use of computers for automatic language translation, though perhaps the more appropriate terminology here would be "human augmentation of computer reasoning." In this area of information analysis, the computer first performs a trial translation of a foreign language text, listing words with alternative meanings as multiple lines in the printed output. Successive, iterative machine cycles reduce the number of alternatives, resolve problems of syntax, and so on, until the final translation is accomplished.

A more advanced method being investigated involves the displaying of trial translations on a display console (Fig. 9). The person examining this output selects the meanings of ambiguous words that are proper to the context, and by using the console controls, feeds them back to the computer. The end result is a better translation, from the standpoint of both style and completeness, than is possible with pure machine methods.

#### ON-LINE PROGRAMMING IN COMMAND AND CONTROL SYSTEMS

In the symposium dealing with "Computer Augmentation of Human Reasoning." The Bunker-Ramo Corporation demonstrated how on-line computing and information processing methods can be used to improve the effectiveness of command and control systems. More specifically, the demonstration used a simulated command and control system such as might be used by a Navy task group commander aboard his ship to control and analyze group operations

Using similar equipment and fully developed programs, the group commander could quickly evaluate various problems associated with mission assignments, control of maneuvers, search and rescue operations, and medical emergency operations.

The Bunker-Ramo computer equipment used in the demonstration with the 85 Control/Display Console consisted of the 130 digital computer, the 170/192 magnetic tape system, and the 141 input output system (for initial input of programs and

data to the computer)—all of them rugged, Mil. Spec. units with a history of successful shipboard applications (Fig. 10).

In brief, this is how the simulated shipboard command and control system works: Items of ship and port information, such as names of ships and ports, ship's maximum speeds, current speeds, port accessibility, repair facilities, and many more, are stored on magnetic tape and identified by labels on the console's left-hand program keyboard. Whenever the commander wants to know how a decision of his would affect task group operations—for instance, how long would it take a given ship to reach another vessel in distress, how long would it take both of them to reach a port with the proper repair facilities, and what would be the effect on other task group assignments—the console operator first presses buttons on the left keyboard to identify the needed facts to the computer. He then uses other console controls and the buttons on the right-hand keyboard, buttons keyed to the computer routines, to cause the calculations to be performed and answers to be displayed on the console.

In order to reduce the amount of equipment and preparatory programming, only a small data base was compiled, and relatively simple problems postulated in the demonstration. Its purpose, however, was not to show a fully implemented system, but rather to indicate the significance of on-line computing techniques in command and control situations. Above all the system using on-line programming is adaptive; it provides the commander with a flexible means of solving any problems that arise for which data is available. Such a system, unlike others, is not limited to dealing only with contingencies that were anticipated when the programs and hardware were being designed.

#### EQUIPMENT DETAILS OF THE BUNKER-RAMO 85 CONTROL/DISPLAY CONSOLE (Fig. 11)

1. ELECTRONIC DISPLAY—Text, symbols, point plots, and lined drawings may be produced on the 12- by 16-inch active display area of the 23-inch aluminized TV-type screen. Each display

ИКОВ. В нашем первом заявлении мы упомянули вспомогательные деньги. Мы хотели бы сделать несколько общих замечаний о поступлении на работу в Американский гимназии сторонника из американского образца и нас сердечно пожелали и правильности дела	ALLIED WITH USA OF THE GOVERNMENT WERE PAID MONEY. UNION FROM WISH TO MAKE SEVERAL GENERAL REMARKS CONCERNING CAUSES DO RELATIVELY Y OF THE AMERICAN GOVERNMENT AND CONSIDERED ONESELF ALSO ITSELF IS ELICITED FOR US SERIOUS DOUBTS OF CORRECTNESS OF PU AT BY
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Figure 9.—Computer translation of Russian to English

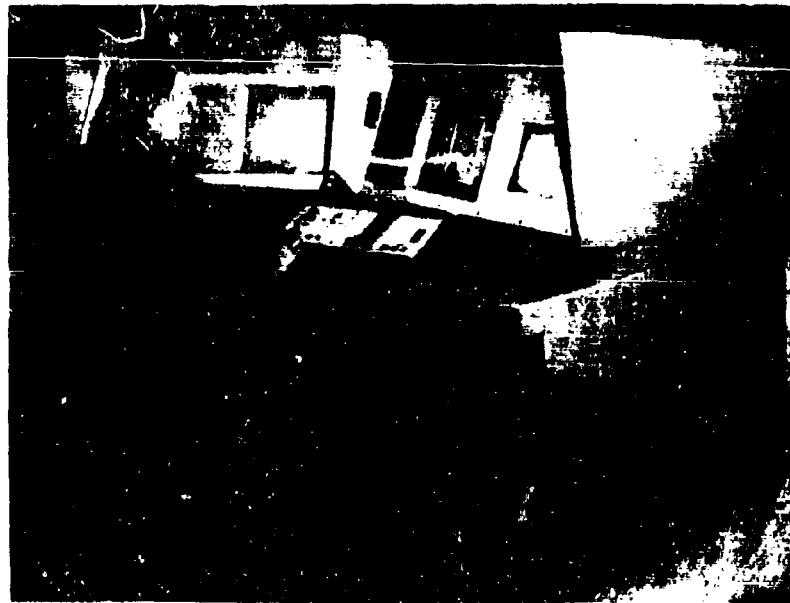


Figure 10.--Display analysis console used in the Bunker-Ramo On-Line Computer Center

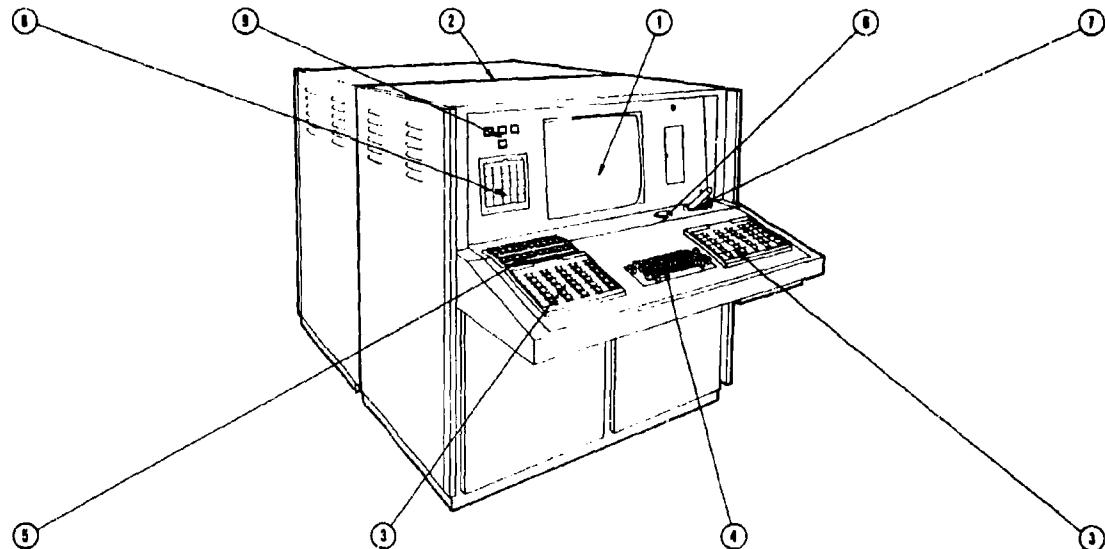


Figure 11.--Type 85 Control/Display Console

element may be placed at any one of 512 positions along any of 384 horizontal lines. Up to 32 lines of 64 alphanumeric symbols may be placed on the screen. Symbols are generated

at the rate of 100,000 per second, may be produced in two sizes, and may be made to blink on the screen.

2. DIGITAL BUFFER UNIT—A 4096-word, 9-bits-per-word magnetic core memory retains the information for the display and refreshes it at from 30 to 60 cycles per second. The computer has random access to the memory and can transfer words into or out of it at 100,000 words per second.

3. PROGRAM KEYBOARD—30 keys, labeled with thin, interchangeable plastic overlays, are used to send messages to the computer. Each of the possible 64 overlays (128 with optional second keyboard) re-identifies the key functions so that it is possible to perform any of 64 (or 128) major programs containing up to 1920 (or 3840) different routines. The light next to each key is controlled by the computer and may be programmed to cue the operator as he uses the keyboard.

4. ALPHANUMERIC KEYBOARD—Used to enter alphanumeric information into the display memory from where it is displayed on the screen. Shift, carriage return, back-space, and advance keys operate like those on an electric typewriter.

5. CONTROL KEYBOARD—Twenty keys and lights to assist the operator in off-line message composition and editing. The operator may create, change, or delete line segments or point plots; he may initiate typewriter mode of operation and copy or delete words or whole lines

of text; he may display different portions of memory or clear them. The keyboard also has control and information functions related to the light gun, the cursor, and the status of the console.

6. CURSOR CONTROL—An electronically generated crosshair pattern may be placed on the screen and moved to any position using the cursor control, a sphere mounted so that it can be freely rotated. Coordinates of the cursor indicate the position of data to be displayed and may be sent to the computer.

7. LIGHT GUN—A photoelectric pointer with which the operator may point to any display element on the screen to identify it to the console logic. The address in display memory producing that element may be used by the console or sent to the computer.

8. STATUS LIGHTS—25 lights labeled by replaceable plastic overlays, and individually controlled by the computer. These lights furnish the operator with program status information and other fixed messages.

9. ERROR LIGHTS—These lights inform the operator that a fault condition exists within the system or that he has committed a procedural error. An "attention" light flashes when any one of the lights comes on.

**PLATO II and III**  
*Coordinated Science Laboratory  
The University of Illinois  
Urbana, Illinois*

## INTRODUCTION

The purpose of the PLATO project (see Digital Computer Newsletter, October 1961, July 1962, April and July 1964) is to develop an automatic teaching system for tutoring, simultaneously, a large number of students in a variety of subjects. The central control element of the teaching system is a general purpose digital computer. The PLATO system differs from most teaching systems in that a single high speed digital computer is used to control all student stations. Thus, it can bring to bear the power of a large digital computer in teaching each student.

## INQUIRY TRAINING

During this quarter the PLATO Inquiry Training lesson (REPLAB) on the bi-metal strip

physics experiment has been rewritten for the PLATO III system. An introductory explanatory sequence for the lesson is being added in preparation for use of the lesson by 60 elementary school students beginning April 1.

## PROOF

A PLATO program for instruction and data collection in mathematical problem solving is being developed for use with the PLATO III equipment. The prototype model, called PROOF, and general characteristics of the new program are described in Coordinated Science Laboratory Report R-186.

## PLATO COMPILER

Three phases of the CATO (Compiler for Automatic Teaching Operations) program have been in progress this quarter.

1. The Fortran resident system was adapted for use with CATO;

2. Major changes in and additions to the Fortran compiler have been coded;

3. Corrections and changes to CATORES, the resident routine for CATO have been made and code checked. CATORES is now a working program.

The logic portion of the CATO compiler is to be grafted to the Fortran system in the very near future. Further improvements, which will facilitate modifications and additions, to the program are planned.

#### INSTRUCTION IN PLATO LESSON PREPARATION

A series of PLATO lessons are being written to teach potential users (authors, not students) the operation of the PLATO system without involving them in all the technical detail. The new PLATO compiler facilitates PLATO

use by non-technical persons wishing to prepare material for PLATO. The approach for the instruction of the PLATO lesson writer is one which progresses from subject matter or psychological objectives to a final logic which can be translated by the compiler into a working program. The illustrative material being used in the lessons is a series in astronomy which has interdisciplinary aspects. The potential user of the PLATO system will follow the astronomy lesson as a student while he is being shown the steps involved in the translation of subject matter from text material to programmed lesson. It is hoped that after completing the instruction series of lessons, persons with a minimum of technical knowledge will be able to prepare material for PLATO fairly easily.

#### PLATO III SYSTEM EQUIPMENT

During this quarter work continued in the development and construction of circuitry required for the realization of a 20-student station teaching system.

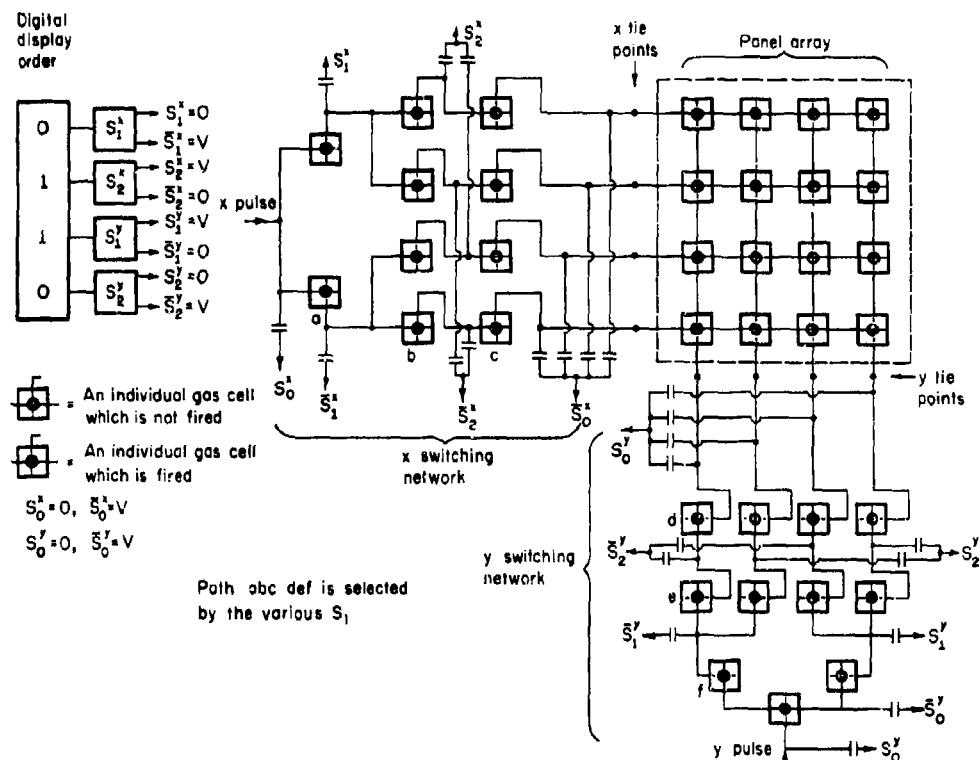


Figure 1.—Direct use of digital display order and response path selected for the order 0110

Circuitry constructed to date includes all logic circuitry required for operation of 8 student stations, all storage tube circuitry required for 2 student stations, all scanner circuitry required for full slide capacity of 122 slides, and all video switch circuitry necessary for 2 student stations. In effect, the above suggests that only 2 student stations are presently operable.

The remaining circuitry required for full operation of 20 student stations is either under construction or undergoing development. Included in circuitry being constructed is logic and storage tube screen protection circuitry. Included in circuitry being developed is storage tube video and deflection circuitry, video switch circuitry, and power control circuitry.

It is expected that progress in the development and construction of circuitry referred to above will yield the first of the remaining 18 student stations during the coming quarter.

#### PLASMA DISCHARGE DISPLAY TUBE

The purpose of the plasma discharge display tube is to develop a less expensive replacement

for the present storage tube system. Work during this quarter has been directed towards a further simplification of the switching network for the plasma discharge display tube.

In the previous progress report we reported that the switching network can be made an integral part of the display device and that isolation networks (R.C. filters) were needed to isolate the switching network from the panel array. The need for the isolation networks has been eliminated by the introduction of a series cell in each line at the tie points to the panel array (Fig. 1). This allows all the tie points in the switching array to be held at the same potential. Since the reference for the x and y switching networks is arbitrary, the x tie points may be held at V and the y tie points at 0. Thus the sustaining voltage for the array is automatically supplied by the switching networks. This choice of reference will cause one of the switching networks to have its input terminal held at V so a series cell is added to put this reference back to zero, as shown in Fig. 1.

In the next quarter we hope to pursue the problem of races and firing of adjacencies within the array.

#### The DIFEQ Program

*Lockheed Missiles and Space Co.  
Palo Alto, California*

A novel program, DIFEQ, has been written for the IBM 7094 computer. Its purpose is the "solution" of systems of ordinary differential equations, i.e., finding numerical values of particular solutions with assigned initial conditions. Although many integration routines have been developed, DIFEQ has several features which distinguish it from other programs.

In addition to providing approximate solution values, the program supplies a rigorous upper bound on the total error of each solution component at each computed point. The user may think of the results as having the form  $Y \pm \epsilon$ , where  $Y$  is the approximate solution and  $\epsilon$  is the error bound. If  $y$  is the exact solution at the given point then  $|y - Y| \leq \epsilon$  holds.

In order to use DIFEQ, the user need only supply his differential equations and initial conditions. The program itself determines all the intrinsic parameters, such as initial and subsequent step sizes, and the like. One implication of this feature is that no reruns will be

necessary to "adjust" various program parameters. The program will yield its best possible results the first time.

In specifying initial conditions and equation constants, inexact data is allowed, i.e., data of the form,  $X \pm \epsilon$ . These initial errors will also be taken into account by the program.

In "scientific" computing, errors accumulate, i.e., errors due to rounding, the replacement of integrals by finite sum approximations, and so on. Often, no error analysis is performed and thus there is no certain knowledge of the accuracy of the final results. In other instances extensive a priori error analysis is performed. This may be a formidable task even for a special case.

To take full advantage of the speed of the automatic digital computer it is desirable that error analysis be mechanized. In 1958, Dr. Ramon E. Moore of Lockheed recognized the possibility of using interval arithmetic as a

means of automatic error analysis by a digital computer. The numerical method used in DIFEQ is a special application of interval arithmetic by Dr. Moore.

Solutions are obtained in a step-by-step fashion by means of expansions in Taylor series truncated at the ninth term. The remainder term in the Taylor series is bounded by the program over intervals it constructs about each new solution point. The step size is chosen so that the solution remains in the interval for all intermediate values between one solution point and the next. This containment is tested by the program. Use of interval arithmetic throughout the computations enables the program to produce rigorously correct upper bounds on the overall error, even including error due to inexact initial conditions, conversion of decimal input to binary in the machine, and so on.

A "macro-expander" program called XPGP, developed under the direction of Mark Halpern

is a part of the DIFEQ routine. A compiler type program utilizes XPGP to generate the required coding for the computation of values of the Taylor coefficients. This is done in such a way that the computing time to get the nth Taylor coefficient goes up only linearly with n. Because of this fact, it is possible to compute efficiently with the nine forms of the Taylor series.

Currently work is underway to improve DIFEQ. Plans include improvement in (1) ease of use, by adding an algebraic compiler type language in which to write the differential equations; (2) generality, by providing various additional options such as: alternate formulas in the differential equations on opposite sides of "discontinuity" points; (3) increased accuracy by adding built-in interval functions for sin, cos, exp, and the like, and by providing for a double precision version. Submission of the program to the IBM SHARE is planned so that potential users throughout the country will have access to the program.

#### Project MAC - Timesharing Demonstrated Across the Atlantic

*Massachusetts Institute of Technology  
Cambridge, Massachusetts*

A future trend in the use of large computer systems was shown by a demonstration in Norway at a meeting of the Norwegian Society for Information Processing. The demonstration was following a talk given by Mr. Lars Monrad-Krohn of the Norwegian Defence Research Establishment, a former DSR Staff Member of Project MAC, Massachusetts Institute of Technology.

This was the first public demonstration of the general use of a computer across the Atlantic,

and it was made possible by the cooperation and assistance of Project MAC, Massachusetts Institute of Technology, RCA and the Norwegian Telegraph Administration.

The programs demonstrated were: a filter design-program, investigating a personnel file on-line, and writing FORTRAN programs which were compiled and run instantaneously.

#### Hybrid Techniques for Real-Time Flight Simulation

*Massachusetts Institute of Technology  
Electronic Systems Laboratory  
Cambridge 39, Massachusetts*

In May 1964 the M.I.T. Electronic Systems Laboratory completed the construction of and demonstrated a hybrid analog-digital computer designed primarily for real-time flight simulation.

The hybrid computer utilizes a Digital Equipment Corporation PDP-1 computer, a 75-ampifier, solid-state analog computer designed and built at M.I.T., and single analog-to-digital and digital-to-analog conversion channels

supplemented by a small, high-speed analog interface.

The model used in the aircraft simulation studies was a complete six-degree-of-freedom representation of the F-100, including engine, fuel flow, atmospheric variations, discrete inputs and outputs, and pilot control inputs. This model was initially solved in real-time using an all-digital program on the PDP-1 alone. The same model was then set up on a hybrid basis,

with the analog equipment serving as a linear, skeleton version of the aircraft and the digital computer providing nonlinear effects, decision management, and engine simulation. It was found that the solution rate of 20 per second employed in the all-digital study could be reduced to 1 per second when the hybrid configuration was used. In effect, such a reduction increases the ultimate real-time capacity of a given computer by a factor of 20 for this important class of problem.

Upon completion of a series of simulation tests, other areas of applied mathematics will be investigated with the hybrid, particularly the

solution of problems formulated in partial differential equation form. Using ad hoc analog and digital equipment various PDE mathematical techniques have been tested experimentally prior to implementation on the hybrid. Such preliminary investigations have been carried out for the diffusion equation, the Orr-Sommerfeld equation of hydrodynamics, the Laplace equation, the wave equation, the Helmholtz equation, and several distributed systems encountered in process control dynamics. To augment the capability of the hybrid computer to handle this class of problems, the parallel development of a high-speed, high-capacity, analog memory has been undertaken.

#### JOSS: An Experimental, On-Line, Time-Shared Computing System

*The RAND Corporation  
Santa Monica, California*

An experimental, on-line, time-shared computing system has been developed and installed for use by staff members on The RAND Corporation, Santa Monica, California. The system, called JOSS for JOHNNIAC Open Shop System, is designed to provide the individual scientist or engineer with an easy, direct way of solving his small numerical problems. A key design feature is that it relieves the user from having to learn to use an operating system, a compiler, and debugging tools; further, he does not have to explain his problems to a professional computer programmer and then check the latter's results after the computations have been run.

The ease and directness of JOSS is attributable to an interpretive routine in the system computer, the JOHNNIAC, which responds quickly to instructions expressed in a simple language developed by J. C. Shaw\* and transmitted over telephone lines from convenient remote electric typewriter consoles. The system has been in daily use since January 1964, and an austere version saw limited use throughout most of 1963. An evaluation of the system has shown that, in spite of severe constraints on speed and size of programs and the use of an over-age machine of the vacuum-tube era, JOSS provides a valuable service for computational needs which cannot be adequately satisfied by conventional,

closed-shop practices. Physically, JOSS consists of the JOHNNIAC computer, 10 remote consoles (in the current rather limited configuration), and a multiple typewriter communication system to mediate between JOHNNIAC and the consoles.

The remote station consoles consist of an IBM model 868 typewriter and a small box with lights and switches to indicate system status and to control the functions of the local communication terminal electronics. The following indicators are provided: a POWER light; an ENABLE light showing that JOSS service is available; a READY light showing that output is acceptable at the typewriter; a red light to show that JOSS controls the typewriter; a green light to show that the user controls it; an IN REQUEST light to show that the user has depressed the IN button for control but JOSS hasn't yet responded; and an OUT REQUEST light to inform the user that JOSS has an administrative message for him (such as "Shutting down at 2330.")

The multiple typewriter communication system provides 16 line-buffers, controls the states of the remote consoles, and registers signals from them. The JOSS system program in JOHNNIAC commands block transfers between core and the line buffers. It also commands the communication system to enable or disable a console, request or relinquish control of a console, clear a line buffer, assign a line buffer to a console, or transmit a line buffer to a console. It also commands the communication system to report action signals from the consoles. The basic JOHNNIAC computer provides no parallel

\*The views expressed herein should not be interpreted as reflecting the views or opinions of The RAND Corporation or the official opinion or policy of any of its governmental or private research sponsors.

processing; however, the multiple typewriter communication system does provide for parallel activity at many consoles, through high-speed line-scanning and time-shared use of the logic circuits. JOSS takes advantage of this independent parallel processing in the communication system by switching its attention rapidly from one user to another to give adequate service to all active users (i.e., by time sharing). Each active user is represented by a block of information which resides on the drum, except when JOSS is actually processing it in core.

JOSS services the requests of users at the remote consoles in such a way that the users' activities are logically independent of one another. Up to 8 of the 10 stations may be served concurrently by the time-sharing techniques. In addition to administering input/output and swaps of user blocks, JOSS interprets and executes both direct and indirect (i.e., stored-program) instructions couched in a readable and easily learned language.

First priority for JOSS' attention goes to the servicing of signals from the consoles: carriage return, page, on, off, in, out and end-of-transmission. JOSS looks for these signals in the communication system when idling, and between interpretive steps when executing a user's program. An end-of-transmission signal requires only that JOSS record that the line buffer is available, and direct the transmission of the next line of output to the same station if one is ready. JOSS then continues with its previous activity. A carriage return, however, like several other signals, requires that JOSS break off its current activity, move the current user's block out to drum, move the signaling user's block into core, and finally, interpret and act on the line of input just released by the carriage return.

Second priority is given to users who have given JOSS output-limited tasks. Third priority is given to users with unfinished tasks, on which JOSS works for two seconds apiece in round-robin fashion. A user's priority changes dynamically according to this discipline, which successfully exploits the parallel processing of the communication system. Under a typical load, JOSS responds to simple requests in a fraction of a second and rarely in as long as 3 seconds. Users who are skilled in typing can maintain impressive rates of interaction with JOSS.

It is convenient to consider JOSS to be a "computing aide" interacting with the user by means of a simple language. The sample problem (Fig. 1) gives some insight into the kinds of JOSS-user interaction that can take place and

```

1.1 Set x(1) = (-b+sqrt(bw^2+4*a*c))/(2*a).
1.2 Set x(2) = (-b-sqrt(bw^2+4*a*c))/2*a.
1.3 Type x.
1.4 Line.

Set a = cos(0).
Set b = -sqrt(4).
Set c = 1.
Do part 1.
  x(1) =      1
  x(2) =      1

Do part 1 for b = -3 -7 -2*log(14).
  x(1) = 2.61803399
  x(2) = .38196601
  x(1) = 6.85410195
  x(2) = .145898035
  x(1) = 5.0813152
  x(2) = .19679944

```

Figure 1.—Sample JOSS program showing user's statement of his problem, the input data, and instructions (all normally typed in green), and the JOSS solutions, here indented five spaces (normally typed in black). The example shows how the use of familiar symbols and a natural language facilitate communication and make JOSS statements readily understandable (the asterisk indicates exponentiation).

suggests the readability of the language and the power of expression.

A striking feature of the system is that the user commands JOSS directly in the same language that he uses to define procedures for JOSS to carry out indirectly. A numeric label as a prefix to a step is an implied command to JOSS to store the step in sequence according to the numerical value of the label. JOSS differs from other on-line systems by requiring the user to supply his own step numbers on all steps of his stored program. Thus, the user always has the option of typing a direct command or an indirect step, without having to explicitly call for another mode to get the desired option. The numeric label determines whether an indirect step is an addition, an insertion, or a replacement for another step.

Elsewhere, the language is very explicit. For example, in conjunction with numerical expressions, it requires full words to denote steps, parts, or output formats (forms). This too contributes to readability. A step is limited to a single line, and a line is limited to a single step, neither being much of a constraint. As a result, a step number serves to identify not only the logical step but the stored string and the typographical line as well. Arbitrarily complex expressions may be used everywhere, except as step label prefixes which must be explicit

decimal numerals. The 52 upper- and lower-case letters are the only identifiers to which the user can assign numerical values.

JOSS represents all numbers internally in scientific notation—nine decimal digits of significance and a base-ten scale factor with an integer exponent in the range -99 through +99. JOSS presents an exact input interface, familiar decimal arithmetic internally, and an exact output interface. Addition, subtraction, multiplication, division, and square root are carried out by JOSS to give true results rounded to nine significant decimal digits (except on overflow which yields an error message, or an underflow for which zero is substituted). The decimal nature of JOSS gives the user easy control over exact calculations that would require especially careful attention in a binary system.

The functions in the language include a set of logical functions which, together with the numerical relations and and and or, lead to powerful direct expressions of conditions which can be attached to any step. Care has been taken in a basic set of elementary functions to hit certain "magic" values on the nose and to provide reasonably full significance of results. The general exponential routine to compute  $a^b$ , for example, factors out error situations and the special cases of  $b = 0$ ,  $a = 0$ ,  $b = 1$ ,  $b$  an integer and a an integer power of 10,  $b = 0.5$ ,  $b = -5$ , and  $b$  an integer with  $2 \leq b \leq 29$ , before resorting to  $\exp [b \cdot \log(a)]$ .

The interpretive technique on which JOSS is based enables the user to edit his stored program freely and quickly—even when JOSS interrupts at the user's request or suspends work on a task to report an error. Inserting and replacing steps or forms is implicit in the treatment of any new line of input. Deleting and typing are called for explicitly and the language provides

"handles" at various levels of aggregation so the user isn't forced to do his editing piecemeal at the level of individual steps, forms, and values. Steps are organized into parts according to the integer parts of the step numbers. Parts then become units that can be typed or deleted, as well as natural units for specifying procedures in hierarchical fashion. Values, too, may be organized into vectors and arrays if indexed letters are used, and letters by themselves may be used to refer to entire arrays for purposes of typing or deleting. Still higher aggregates may be typed or deleted by using the expressions: all steps, all parts, all forms, all values, and all.

The goal of the JOSS experiment has been to provide personal computing service especially useful to RAND's technical staff. Emphasis has been placed on the development of a tool for problem-solving rather than just answer-getting and production computing. Although the present system is limited by too few stations and the unreliability of the 12-year-old vacuum-tube computer, over 150 RAND staff members are using the 10 stations distributed throughout the building.

Based on the daily usage log and judging from reports from users, JOSS does provide a personalized computer service not previously available. The exceedingly close interaction between the user and JOSS via the "conversational" language results in a very productive mode of operation for most users. It is interesting to note that JOSS has attracted many users with no prior programming experience. A number of RAND staff members have turned to JOSS as an effective and helpful "assistant" even though other alternatives are available—such as open-shop programming, available service programmers, and computing aides.

**Digital Fire Control R&D Facilities**  
U.S. Navy Bureau of Naval Weapons (RRRE-31)  
Washington, D.C. 20360

## INTRODUCTION

The special equipment test facility located on the G-1 Guided-Missile Range at NOTS has been designed for the experimental test and pre-prototype evaluation of new concepts and equipments relating to both digital and analog surface fire control systems. Basic considerations governing the setting up of the installation were flexibility and adaptability of test facility equipments and their components. For

example, electrical connections are set up so that an entire unit (or any component of a unit) of experimental equipment can be inserted easily for evaluation, and additional testing equipment can be incorporated at any point in the system.

Figure 1 is an R&D facilities schematic. The solid lines represent the present R&D set-up; the broken lines show future R&D equipment plus other G-1 Range equipment and instrumentation adaptable for use in surface fire control

equipment testing and evaluation. The facility is available for use by activities operating under Navy auspices. For information and scheduling criteria, contact the Instrument Development Division, Attention Code 3042, U.S. Naval Ordnance Test Station, China Lake, California, 93557. The Digital Fire Control (DFC) Radar, the DFC UNIVAC 1218 Process Controller, and the Digital-Analog Servo System are described below.

The digital fire control (DFC) radar system is basically a monopulse type target-tracking radar system operating in the X-band range. The transmitter is a tunable magnetron with a peak power of 250 kw. Pulse repetition frequency is 1000 pps. Operation is continuous in azimuth. Tracking modes are manual, aided, and automatic.

**Tracking rates:** Range . . . . . 1,000 yd/sec  
Azimuth . . . . . 750 mils/sec  
Elevation . . . . . 750 mils/sec

**Slewing rates:** Range . . . . . 12,000 yd/sec  
Azimuth . . . . . 750 mils/sec  
Elevation . . . . . 750 mils/sec

The digital range unit, designed at NOTS for use with this radar, modified the range capabilities as follows:

Range . . . . . . . . . 130,000 yd  
Range rate . . . . . . . . . 3,000 yd/sec  
Acceleration limits (selectable)  
(low gain) . . . . . . . . . 10 g  
(low gain 'out') . . . . . . . . . 90 g

The digital range unit has a least significant bit of 1 yard with a repeatability of  $\pm 1$  yard.

The DFC radar with the digital range unit has a real-time readout of azimuth, elevation, and range to the DFC UNIVAC 1218 computer, and a record of IBM 7094 compatible tape for data reduction. Visual (decimal) readout presentation is available at the radar building console. In the readout, velocity is presented in yards per second, range is given in yards, and azimuth and elevation are recorded in mils or degrees.

This radar system can receive digital target acquisition information in azimuth, elevation,

and range from the digital-to-analog servo system (DASS).

#### DIGITAL FIRE CONTROL (DFC) UNIVAC 1218 PROCESS CONTROLLER

The UNIVAC 1218 is a general-purpose, stored-program, real-time digital computer. It has a magnetic-core memory with a 16,384-word capacity. Word length is 18 bits. Eight input and eight output channels are available. Each channel provides 18 parallel data lines plus necessary control lines. Channels can be paired to form 36-bit dual channels. The computer has a repertoire of 98 flexible instructions and 32 nondestruct memory locations for initial load and automatic-recovery routine.

There are two UNIVAC 1218 computers on G-1: One is in the DVC system; the other is part of the range control system (RCS). The one used in the DFC system does not have the peripheral gear associated with the computer. Computer instructions are transmitted from magnetic or paper tape through the RCS unit and a connecting cable to the DFC computer. Program-loading encompasses a single (18-bit) parallel transfer or a dual (36 bit) parallel transfer computer-to-computer capability. Separate cabling—45 twisted-pair per cable—is installed for input and output functions.

Inputs to the DFC UNIVAC 1218 computer are:

DFC radar range, azimuth, and elevation  
Passive-tracking unit azimuth, elevation, and tracking error (proposed)  
IRIG (Inter-Range Instrumentation Group)  
"Time of Day"  
Programming (instructions)  
Outputs from the computer include:  
Launcher pointing information to DASS  
Computed data to recorder

#### DIGITAL-ANALOG SERVO SYSTEM (DASS)

DASS, designed and developed at NOTS as part of the surface weapon fire control supporting research program, accepts digital-position data from shaft-angle encoders on the Mk 5 Mod 1 launcher, and digital target-position and velocity data from the DFC UNIVAC 1218 computer.

The computer position information is updated by integrating the velocity, and then comparing it with the encoder position readout to obtain an error signal; errors in bearing and elevation and rate of change of errors are then translated to analog signals (DC voltages proportional to the error) and sent to the launcher drive elements to correct the launcher aimpoint. Figure 2 is a block diagram of the digital-analog servo system.

DASS serves in shipboard fire control systems as the link between the computer and the launcher. It accepts computer positioning and velocity data, extrapolates between computer outputs to update launcher positioning data, compares the extrapolated data with position information from the launcher, and continually sends new positioning and velocity data to the launcher drive elements.

The primary function of the servo loop is to translate digital-computer outputs into the analog form required by the launcher. Additionally, the updating elements of DASS provide intermediate outputs to keep the launcher from being driven in large step increments, which would cause it to hunt.

#### Parameters

Computer output rate . . . . .	10 cps to 2 kc
Updating rate . . . . .	250 cps to 2 kc
Position error . . . . .	50 cps to 2 kc
Rate of change of position error, output transfer rate . . . . .	200 cps to 2 kc

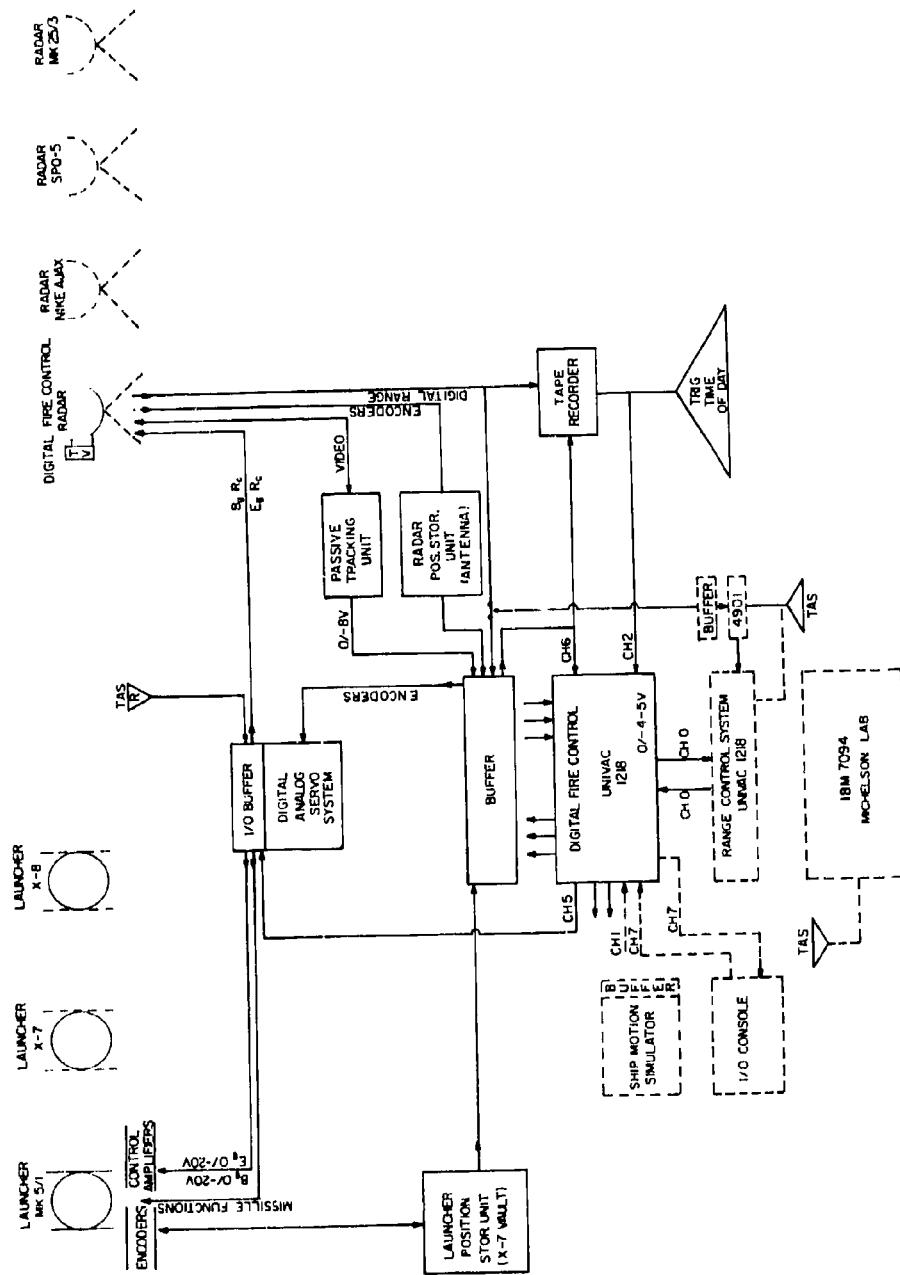


Figure 1.—R&D facilities schematic

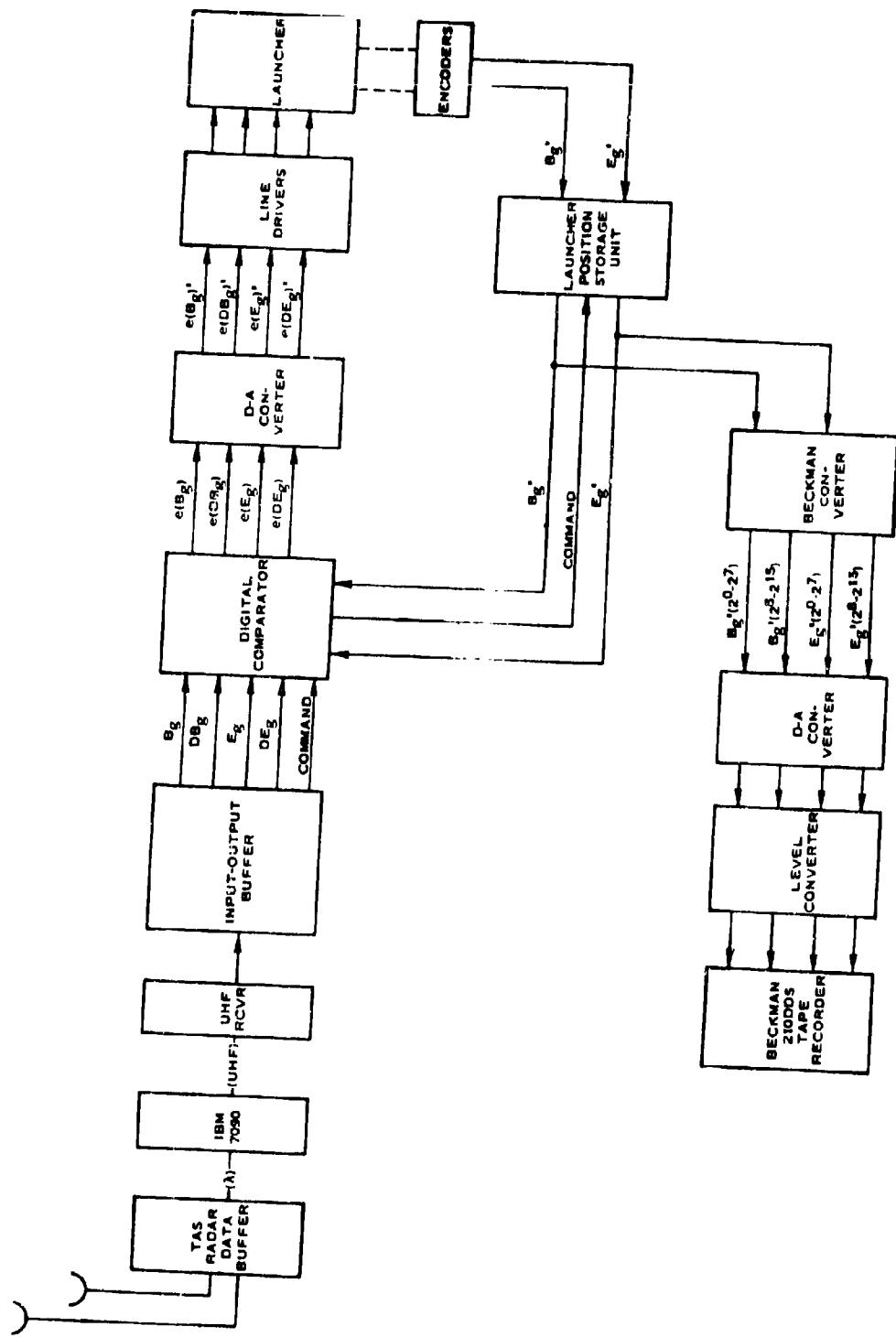


Figure 2.—Digital-analog servo system